Buffalo for safe food and sustainable production

Proceedings of the

11th ASIAN BUFFALO CONGRESS

25-27th October, 2024
BCDM, Savar, Dhaka, Bangladesh
Buffalo Breeding and Development Farm, Savar, Dhaka, Bangladesh

Organized by:

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INTERNATIONAL BUFFALO FEDERATION

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Adviser
Ministry of Fisheries & Livestock
Govt. of the People's Republic of Bangladesh
Bangladesh Secretariate, Dhaka

I am delighted that Bangladesh, for the first time, is hosting the 11th Asian Buffalo Congress (ABC 2024) from 25 to 27 October 2024. Buffalo, once regarded as a draught animal, is now recognised as a dairy animal due to the outstanding food value of its milk. Asia alone houses 97% of the world buffalo population of 208 million heads. This species contributes 15% of the total milk produced in the world. However, 99% of the buffalo milk and 96% of the buffalo meat are produced in the Asian region. Dairy and meat products derived from buffalo are highly nutritious and meet human needs for high-quality protein. It is also a livelihood initiative for rural communities. It is important that all stakeholders and scientists involved in buffalo production and research contribute to a global strategy that addresses global food and environmental challenges.

Under this backdrop, Asian Buffalo Association (ABA), in cooperation with Bangladesh Buffalo Association (BBA), Department of Livestock Services (DLS), Bangladesh Livestock Research Institute (BLRI) and Bangladesh Agricultural University (BAU), have teamed up to host the 11th ABC 2024 at BCDM, Savar, Dhaka, Bangladesh. I am pleased to know that more than 200 national and international delegates, including scientists, professors, researchers, policymakers, graduate students, commercial farmers, media persons, and other stakeholders are participating in this august congress. The outcomes of this congress, including the recommendations, would be cornerstones for the buffalo sector's research and development.

I would like to thank and congratulate the members of all committees of the Congress for bringing out this valuable Proceedings of the 11th ABC 2024 and for their tireless efforts to make this congress an ever-memorable event. I wish the grand success of the 11th ABC 2024.

(Farida Akhter)

MESSAGE

Secretary
Ministry of Fisheries & Livestock
Govt. of the People's Republic of Bangladesh
Bangladesh Secretariate, Dhaka

I am very pleased to know that, Bangladesh is going to organize 11th Asian Buffalo Congress (ABC 2024) from 25-27 October, 2024. This will be the 1st international conference on buffalo in Bangladesh. Buffalo is popularly known as Black Gold in Asia. It contributes significantly in national economy of Bangladesh mainly through milk, meat, draft power and organic manure. It is the main source for the food security, income generation and livelihood enhancement of the smallholder farmers. The theme of this 11th Asian Buffalo Congress is "Buffalo for Safe Food and sustainable production". It is highly relevant in the context of developing countries like Bangladesh. Ministry of Fisheries and Livestock (MoFL) is directly involve for buffalo development in Bangladesh and is therefore, funding buffalo development program run by Department of Livestock Services (DLS) and Bangladesh Livestock Research Institute (BLRI). Through these programs, necessary infrastructure for genetic improvement of buffaloes of Bangladesh and research facilities on nutrition, reproduction, health and management are being developed.

I am delighted to know that about 200 National and International delegates throughout the world are participating in this congress where more than 130 scientific papers in different fields like buffalo nutrition, health, management, market dynamics and breeding including genomic selection, molecular techniques are discussed in the event. I hope that this event will be a milestone for sharing global, modern and innovative activities on buffalo research and development.

I congratulate the advisory committee, organizing committee, IT committee and the secretariate of this congress for their hard works to bring out of this valuable Proceedings of the 11th ABC 2024 and making the event ever successful and memorable. I wish a good fortune of the 11th ABC 2024.

(Sayeed Mahmood Belal Haider)

Vice-Chancellor
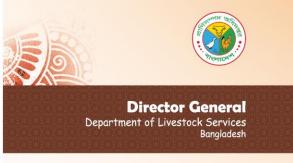Bangladesh Agricultural University
Mymensingh, Bangladesh

I am pleased to know that Bangladesh, for the first time, is hosting 11th Asian Buffalo Congress (ABC 2024) from 25 to 27 October, 2024. Buffalo once regarded as draught animal is now honoured as dairy animal. Asia alone houses 97.04% of the world buffalo population of 208 million heads. However, 98.91% of the buffalo milk and 96.44% of the buffalo meat are produced in the Asian region. It is important that all stakeholders and scientists involved in buffalo production and research of Asia contribute to a global strategy that addresses global food and environmental challenges. Bangladesh Agricultural University is involved for producing quality graduates who are engaged in buffalo development in Bangladesh and is also involved in conducting basic research on different disciplines of buffaloes in Bangladesh.

Under this backdrop, Asian Buffalo Association (ABA), in cooperation with Bangladesh Buffalo Association (BBA), Department of the Livestock Services (DLS), Bangladesh Livestock Research Institute (BLRI), and Bangladesh Agricultural University (BAU) have teamed-up to host the 11th ABC 2024 at BCDM, Savar, Dhaka, Bangladesh. I am pleased to know that a large number of national and international delegates including scientists, professors, researchers, policy makers, graduate students, commercial farmers, media persons and other stakeholders are participating in this August Congress.

I would like to thank and congratulate the members of all committees of the Congress for bringing out this valuable Proceedings of the 11th ABC 2024 and for their tireless efforts to make this congress an ever-memorable event. I wish for the grand success of the 11th ABC 2024.

(Professor Dr. A.K. Fazlul Haque Bhuiyan)

M E S S A G E

Director General
Department of Livestock Services
Bangladesh

I am very pleased to know that, Bangladesh is going to organize 11th Asian Buffalo Congress (ABC 2024) during 25-27 October, 2024. This will be the 1st international conference on buffalo in Bangladesh. Buffalo is popularly known as Black Gold in Asia. It contributes significantly in national economy of Bangladesh mainly through milk, meat, draft power and organic manure. It is the main source for the food security, income generation and livelihood enhancement of the many of the smallholder farmers. The theme of this 11th Asian Buffalo Congress is "Buffalo for safe food and sustainable production". It is highly relevant in the context of developing countries like Bangladesh. Department of Livestock Services (DLS), Bangladesh is directly involve for buffalo development in Bangladesh and is therefore, running buffalo development program. Through this program, necessary infrastructure for genetic improvement of buffaloes of Bangladesh has been developed.

I came to know that about 200 delegates from 12 countries throughout the world are participating in this congress where more than 130 scientific papers in different fields like buffalo nutrition, health, management, market dynamics and breeding including genomic selection, molecular techniques will be discussed in the event. I hope that this event will be a milestone for sharing global, modern and innovative, activities on buffalo research and development.

I would like to thank the International Buffalo Foundation, Asian Buffalo Association and Bangladesh Buffalo Association for supporting this event in Bangladesh. I acknowledge DLS, Dhaka; BLRI, Savar and Bangladesh Agricultural University (BAU), Mymensingh and numerous stakeholders for their efforts in hosting the ABC 2024. I congratulate the advisory committee, organizing committee, IT committee and the secretariate of this congress for their hard works for bringing out this valuable proceedings of the 11th ABC 2024 and making the event ever successful and memorable. I wish a grand success of the 11th ABC 2024 and hope that the feedback and recommendation that come out from this congress will be highly valuable for policy makers and all the stakeholders including farmers in Bangladesh as well as in the world.

(Dr. Md. Reajul Huq)

Director General
Bangladesh Livestock Research Institute (BLRI)
Savar, Dhaka, Bangladesh

I am happy to know that the Bangladesh Buffalo Association is going to organize the 11th Asian Buffalo Congress (ABC 2024) from 25-27 October, 2024. It will be the 1st international conference on buffalo in Bangladesh. Buffalo contributes significantly to Bangladesh's national economy by providing milk, meat, draft power, and organic manure. It is the leading source for food security, income generation, and livelihood enhancement for smallholder farmers. The theme of this 11th Asian Buffalo Congress is "Buffalo for Safe Food and Sustainable Production". It is highly relevant in the context of developing countries like Bangladesh. Bangladesh Livestock Research Institute (BLRI) is directly involved in buffalo development in Bangladesh. BLRI is implementing research and development activities in different areas of buffalo production. BLRI can collaborate with other organizations from home and abroad in the cutting edge technology and knowledge development research process.

It's a unique opportunity to learn and share knowledge at the 11th Asian Buffalo Congress. I am delighted to learn that a large number of delegates from 8 countries are participating in this congress. More than 130 scientific articles in different fields like buffalo nutrition, health, management, market dynamics and breeding including genomic selection, molecular techniques are up for discussion. I am confident that this event will be a milestone for sharing global, modern and innovative activities on buffalo research and development.

I would like to extend my heartfelt thanks to the advisory committee, organizing committee, IT committee and the secretariate of this congress. Their hard work and dedication have been instrumental in bringing out the valuable Proceedings of the 11th Asian Buffalo Congress. I am confident that their efforts will make the event a grand success and a memorable experience for all. The feedback and recommendations that come out from this congress will be precious for policymakers and all the stakeholders, including farmers in Bangladesh and around the world.

(Dr. S. M. Jahangir Hossain)

On behalf of the standing committee of International Buffalo Federation, I would like to congratulate Bangladesh Buffalo Association and the agencies involved in the organization of the 11th Asian Buffalo Congress in Bangladesh from 25-27 October, 2024. Our estimation is particularly for Professor Dr. Md. Omar Faruque, President of Asian Buffalo Association who organized this important event.

It is a signal of continuity in the normal agenda of congress held under the umbrella of IBF, particularly for Asia, where buffalo plays a pivotal role in the economy of the families and the countries, producing milk, meat, leather, dung and other by-products, giving a significant support for food security and livelihood. The title of the congress is right and adequate: Buffalo for safe food and sustainable production. My best wishes for the best success of the congress.

Antonio Borghese

(Professor Antonio Borghese)

MESSAGE

Buffalo once regarded as draught animal is now honoured as dairy animal due to outstanding food value of its milk. Asia alone houses 97.04% of the world buffalo population of 208 million heads. India houses 57.8% of the world buffalo population, followed by 18.9% in Pakistan and 11.6% in China. However, it is found in all the continents of the world thus becoming a global animal. Out of 16 well defined and recognized breed of buffalo, Asia alone possesses 15 breeds. This species contributes 15% of the total milk produced in the world. However, 98.91% of the buffalo milk and 96.44% of the buffalo meat are produced in the Asian region. Thanks to predominant contribution of Asian buffalo as the top buffalo milk and meat producing species in the world.

The number of buffalo is increasing in India, Pakistan, Nepal, China, Italy, South America and some part of the world. However, the number of buffalo is decreasing in South east Asia, Sri-Lanka, Bangladesh and other countries. It is important that all stakeholders and scientists involved in buffalo production and research contribute to a global strategy that addresses global food and environmental challenges. To address those facts, the theme of the 11th Asian Buffalo Congress has been chosen as "Buffalo for safe food and sustainable production".

I would like to thank the International Buffalo Foundation, Asian Buffalo Association and Bangladesh Buffalo Association for supporting this event to be hosted by Bangladesh. I acknowledge DLS, Dhaka; BLRI, Savar and Bangladesh Agricultural University and numerous stakeholders for their efforts in hosting the ABC 2024. I congratulate the advisory committee, organizing committee, IT committee and the secretariate of this congress for their hard works to bringing out this valuable Proceedings of the 11th ABC 2024 and making the event ever successful and memorable. I wish a grand success of the 11th ABC 2024 and hope that the feedback and recommendation that come out from this congress will be highly valuable for policy makers and all the stakeholders including farmers in Bangladesh as well as in the world.

(Professor Dr. Md. Omar Faruque)

It is exciting to know that Bangladesh will host the 11th Asian Buffalo Congress (ABC 2024) from October 25-27, marking its first international buffalo conference in the country. Buffaloes, known as "Black Gold" in Asia, plays a crucial role in the region's economies through milk, meat, draft power, and organic manure production. This year's theme, "Buffalo for Safe Food and Sustainable Production," underscores their importance in sustainable agriculture.

The Asian Buffalo Association (ABA) coordinates the Congress, held every three years in different Asian countries. For ABC 2024, ABA has teamed up with the Bangladesh Buffalo Association, Department of Livestock Services, Bangladesh Livestock Research Institute, and Bangladesh Agricultural University to organize this event in Dhaka.

Over 200 delegates from nine countries will participate, with more than 130 scientific papers addressing critical topics like buffalo nutrition, health, management, market dynamics, breeding, genomic selection, and molecular techniques. This Congress promises to be a significant milestone in advancing buffalo research and fostering global collaboration.

I extend heartfelt appreciation to ABA President, Prof. Dr. Omar Faruque, for his efforts in organizing this event, and to Dr. Inderjeet Singh, Vice President of ABA, for his valuable guidance. Congratulations to the advisory and organizing committees for making this event a success. I wish the 11th Asian Buffalo Congress great success and a lasting impact on the global buffalo community.

(Dr. Ashok Kumar Balhara)

MESSAGE

It is our opportunity to host the 11th Asian Buffalo Congress in Bangladesh. This is the first international conference on buffalo in Bangladesh. Thanks to the members of Asian Buffalo Association to give us such opportunity. Buffalo is one of the important domestic animal in Bangladesh and play important role in the rural economy here through supply of food (milk and meat), creating employment opportunity and improving living standard of farmers. Buffalo was used as draught animal in the past in Bangladesh. It is now used for production of milk and meat.

Buffalo farming especially dairy buffalo farming is getting popularity due to the unique food value of buffalo milk and meat, the low production cost of buffalo rearing and its capacity to adjust with diversified environment. The theme of the congress "Buffalo for Safe Food and Sustainable Production" is quite right to those properties associated with buffalo.

The 11th Asian Buffalo Congress, 2024 provides the opportunity to all stakeholders of Bangladesh including farmers, researchers and policy makers to acquire more knowledge about buffalo rearing and utilization though scientific presentation on different disciplines like buffalo breeding and reproduction, buffalo feeding and nutrition, Buffalo genomics and biotechnology, Buffalo management, economy and sociology, Buffalo ecology, climate, welfare and sustainability, Buffalo health and adaptability, buffalo products processing technology. The congress provides a unique platform of networking among the scientists, professionals and policy makers not only from Asia, but also from all over the world. Moreover, the scientific deliberations, knowledge sharing and discussions during the Congress adds more scientific value on buffalo research and help addressing the key issues of buffalo production and its sustainable development.

I would like to thank the International Buffalo Federation, Asian Buffalo Association and Bangladesh Buffalo Association for supporting this event in Bangladesh. I acknowledge DLS, Dhaka, BLRI, Savar and Bangladesh Agricultural University and numerous stakeholders for their efforts in hosting the ABC 2024. I congratulate the advisory committee, organizing committee, IT committee and the secretariat of this congress for their hard works for bringing out of this valuable Proceedings of the 11th ABC 2024 and making the event ever successful and memorable. I wish a grand success of the 11th ABC 2024 and hope that the feedback and recommendation that come out from this congress will be highly valuable for policy makers and all the stakeholders including farmers in Bangladesh as well as in the world.

Dr. Hiranmoy Biswas

Convener
Technical Committee, ABC 2024
Dhaka, Bangladesh

Organising 11th Asian Buffalo congress in Bangladesh from 25 to 27 October, 2024 brings us great joy and enjoyment. Buffalo is one of the most important domestic animals in Bangladesh as well as in Asia. It is also known as "Black Gold" that plays a vital role in regional economy through milk, meat draft power and organic manure production. Asia alone houses 97% of the world's buffalo. Here, 99% of the buffalo milk and 96% of the buffalo meat is produced. Moreover, dairy and meat products derived from buffalo are highly nutritious.

The Asian Buffalo Association (ABA) Coordinates the congress, held every three years in different Asian countries. This year Asian Buffalo Association (ABA) and Bangladesh Buffalo Association (BBA) in cooperation with Department of Livestock Services (DLS), Bangladesh Livestock Research Institute (BLRI) and Bangladesh Agricultural University (BAU) are organising the congress with the theme "Buffalo for safe food and sustainable production". "11th Asian Buffalo congress 2024" will encourage all the stakeholders related to Buffalo production.

Compared to the previous conference, this year's event has more scientific papers and report discussions and the number of participants is also high, which is very pleasing and encouraging. I would like to thank all the members of the technical sub-committee and all others for their tremendous contribution that have helped us to complete publication of different scientific proceedings.

I wish this event a success and appreciate the organisers for working relentlessly to make it happen.

(Professor Dr. Md. Ruhul Amin)

MESSAGE

Member Secretary
Technical Committee, ABC 2024
Dhaka, Bangladesh

I am very much delighted that Asian Buffalo Association (ABA) and Bangladesh Buffalo Association (BBA) are going to organise "11th Asian Buffalo Congress" during 25 to 27, October, 2024 with the theme "Buffalo for safe food and sustainable production". Livestock plays a pivotal role in the world's food safety and economy. Buffalo is one of the most important livestock in Asia and plays a vital role in the rural economy in this region through supplying food (milk and meat), creating employment opportunities and improving the living standard of farmers.

The 11th Asian Buffalo Congress-2024 will be supported by the Department of Livestock Services (DLS), Bangladesh Livestock Research Institute (BLRI) and Bangladesh Agricultural University (BAU). This year around 200 delegates throughout the world will participate in this congress. They will discuss different scientific findings on buffalo research. This year we have received around 200 scientific papers in different fields like buffalo nutrition, health, management, product processing, market dynamics and breeding including genomic selection, molecular techniques etc. We tried our level best to handle these scientific reports and published these proceedings on the eve of 11th Asian Buffalo Congress. Finally, around 100 scientific papers will be published and discussed in different segments of this congress. This event will be a milestone for sharing global, modern and innovative activities on buffalo research and development.

I would like to convey my heartfelt thanks to all the authors, reviewers, post graduate students of the dairy chemistry and technology laboratory and dairy cattle production laboratory, members of the technical sub-committee and others for their contribution in publishing these scientific reports.

Finally, we tried our level best to ensure the quality of the proceeding, however, for any sort of deviation, I apologize.

(Professor Dr. Mohammad Ashiqul Islam)

11th ASIAN BUFFALO CONGRESS

PROGRAM

09.00-10.00	:	*Registration*
10.00-10.10	:	*Opening of the congress* **Farida Akter,** Adviser, Ministry of Fisheries and Livestock, GoB, Dhaka, Bangladesh.
10.10-10.30	:	*Welcome address* **Dr. Ashok Kumar Balhara,** Secretary, Asian Buffalo Association
10.30-11.00	:	*Thematic paper* "Buffalo for safe food and sustainable development" **Dr. T.K. Datta,** Director, ICAR-CIRB, Hisar, India.
11.00-11.15	:	*Special guest Speech* **Professor Antonio Borghese,** Secretary, International Buffalo Federation, Rome, Italy.
11.15-11.25	:	*Special guest speech* **Dr. Md. Reajul Huq,** Director General Department of Livestock Services, Farm Gate, Dhaka, Bangladesh.
11.25-11.35	:	*Special guest speech* **Dr. S M Jahangir Hossain,** Director General Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh.
11.35-11.45	:	*Special guest speech* **Dr. Sayeed Mahmood Belal Haider,** Secretary, Ministry of Fisheries and Livestock GoB, Dhaka, Bangladesh.
11.45-11.55	:	*Guest of Honour speech* **Prof. Dr. A.K. Fazlul Haque Bhuiyan,** Vice-chancellor Bangladesh Agricultural University, Mymensingh, Bangladesh.
11.55-12.10	:	*Chief guest speech* **Farida Akter,** Adviser, Ministry of Fisheries and Livestock , Dhaka, Bangladesh.
12.10-12.20	:	*Vote of thanks* **Dr. Hiranmoy Biswas,** Secretary, Local organizing committee, ABC, 2024.
12.20-12.30	:	*President speech* **Prof. Dr. Md. Omar Faruque,** President, Local organizing committee ABC, 2024 & Asian Buffalo Association.
12.30-14.30	:	Lunch and prayer

Invited papers

Chair	:	**Dr. Sayeed Mahmood Belal Haider**
		Secretary, Ministry of Fisheries and Livestock, GoB, Dhaka, Bangladesh.
Co-Chair	:	**Dr. Md. Reajul Huq**
		Director General, Department of Livestock Services, Farm Gate, Dhaka, Bangladesh.
		Professor Dr. Bhuminand Devkota
		University of Agriculture and Forestry, Chitwan, Nepal.

14.30-15.00 : The potential of water buffalo in world agriculture: challenges and opportunities
Professor Antonio Borghese, Secretary General
International Buffalo Federation, Rome, Italy.

15.00-15.30 : Buffalo for sustainable dairying
Dr. Inderjeet Singh, Vice President, Asian Buffalo Association, India.

15.30-16.00 : Feeding of buffaloes based on local feed resources to enhance rumen fermentation efficiency and mitigate methane emission
Professor Dr. Metha Wanapat, Khon Kaen University, Thailand.

16.00-16.15 : Tea Break

Scientific Session

Buffalo ecology, climate, welfare and sustainability

Chair	:	**Mr. A.T. M. Mostafa Kamal**
		Additional Secretary (Livestock), Ministry of Fisheries and Livestock, GoB, Dhaka, Bangladesh.
Co-Chair	:	**Dr. S M Jahangir Hossain**
		Director General, Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh.
		Mr. Hasibur Rahman
		Additional Deputy Managing Director, ACME Laboratories Ltd., Dhaka, Bangladesh.

16.15-16.40 : *Keynote paper*
Buffalo contributes to sustainability during the climatic change era
Dr. Antonella Chiariotti
Research Centre for Animal Production and Aquaculture, Rome, Italy.
Oral presentation

16.40-16.50 : Waste management practices of buffalo farms in selected areas of Bangladesh
Md. Manik Miah, Buffalo Research and Development Project, Buffalo Production
Research Division, Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh.

16.50-17.00 : Transforming buffalo farming in the climate change landscape of Bangladesh
S. M. Rajiur Rahman. Ph.D., National Dairy and Nutrition Expert, Clean and
Energy Efficient Cooling for Livestock Supply Chains in Bangladesh
IRG-World Bank Group, Dhaka, Bangladesh.

17.00-17.10 : Redesigning buffalo farming practices in Bangladesh toward a sustainable
milk production system
Unusing Marma, Department of Medicine and Surgery
Chattogram Veterinary and Animal Sciences University (CVASU)
Chattogram-4225, Bangladesh.

16.00-17.30 : *Poster presentation*

Scientific Session

Buffalo breeding and reproduction

Chair	:	**Dr. Inderjeet Singh** Vice-Chancellor, Guru Angad Dev Veterinary and Animal Sciences University Ludhiana, Punjab, India.
Co-Chair	:	**Prof. Dr. MAM Yahia Khandoke**r Department of Animal Breeding and Genetics Bangladesh Agricultural University, Mymensingh, Bangladesh.
		Dr. Mohammad Bozlur Rahman Director Planning, Department of Livestock Services, Dhaka, Bangladesh.
09:00-09:15	:	*Keynote paper* Reproductive strategies in buffaloes: salient achievements and future challenges **Professor Dr. Nasim Ahmed,** Professor Emeritus, University of Veterinary and Animal Sciences, Lahore, Pakistan. *Oral presentation*
09:15-09:25	:	Progesterone impregnated intravaginal sponge device for reproductive management in buffalo **Professor Dr. Bhuminand Devkota,** Department of Theriogenology, Agriculture and Forestry University, Chitwan, Nepal.
09:25-09:35	:	Interferon-tau and pregnancy associated glycoproteins as early markers of pregnancy in buffalo **Professor Olimpia Barbato,** Department of Veterinary Medicine University of Perugia, 06100 Perugia, Italy.
09:35-09:45	:	Time of artificial insemination after GnRH administration on reproductive performances of synchronized native buffaloes in Bangladesh **Professor Dr Mohammad Moniruzzaman,** Department of Animal Science Bangladesh Agricultural University, Bangladesh.
09:45-09:55	:	Developmental competence and molecular signatures of cloned and recloned embryos derived from (non-) transgenic cloned buffaloes **Dr. Chun-Yan Yang,** Guangxi Key Laboratory of Buffalo Genetics Reproduction and Breeding, Guangxi Buffalo Research Institute, Chinese Academy of Agricultural Sciences, Nanning 530001, China.
09:55-10:05	:	Genetic parameters for growth traits in Thai swamp buffaloes **Sarochita Sangjong,** Tropical Animal Genetic Special Research Unit Department of Animal Science, Faculty of Agriculture, Kasetsart University Bangkok 10900, Thailand.
10:05-10:15	:	Oestrus detection based on accelerometer monitoring system in buffalo cows: preliminary results **Dr Vittoria Lucia Barile,** Senior Researcher, Council for Agricultural Research and Economics Research Centre for Animal Production and Aquaculture, Via Salaria, 31 00015 Monterotondo, Rome, Italy.
10:15-10:25	:	Strategic crossbreeding to enhance milk yield for sustainable buffalo production in Bangladesh **Dr. Md. Shahjahan,** Lal Teer Livestock Development (BD) Limited Uthura, Bhaluka, Mymensingh 2240, Bangladesh.
09.00-10.30	:	*Poster presentation*
10:25-10:40	:	Tea Break

Scientific Session

Buffalo feeding and nutrition

Chair   : **Prof Dr. M. A. Akbar**
Former Vice Chancellor, Bangladesh Agricultural University, Mymensingh, Bangladesh

Co-Chair   : **Dr. Nasrin Sultana**
Director (Research), Bangladesh Livestock Research Institute, Savar, Bangladesh

Dr. Nathu Ram Sarker
Executive Director, Krishi Gobeshona Foundation, Dhaka, Bangladesh

10:40-10:55 : *Keynote paper*
Alternatives to antimicrobials for ensuring gut health and
augmenting performance in buffalo calves
Dr. Sachin Kumar, Rumen Biotechnology Lab, Animal Nutrition Division
ICAR-National Dairy Research Institute, Karnal, Haryana-132001, India

Oral presentation

10:55-11:05 : Adaption of improved feeding technologies in buffalo farming
Md. Saiful Islam, Buffalo Research and Development Project
Bangladesh Livestock Research Institute, Savar, Dhaka 1341, Bangladesh

11:05-11:20 : Protein-rich pellet starter enhance body weight gain in suckle buffalo calves
Md. Ashadul Alam, Buffalo Research and Development Project
Bangladesh Livestock Research Institute, Savar, Dhaka 1341, Bangladesh

10:30-11.30 : *Poster presentation*

Scientific Session

Buffalo products processing technology

Chair   : **Prof. Dr. Md. Nurul Islam**
Treasurer, Asian University of Bangladesh, Dhaka and Former Dean, Faculty of
Animal Husbandry, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Co-Chair   : **Prof. Dr. Md. Harun-ur-Rashid**
Department of Dairy Science, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Dr. A. B. M. Khaleduzzaman
Director Production, Department of Livestock Services, Dhaka, Bangladesh

11:30-11:50 : *Keynote Paper*
Water buffalo milk use in insular Southeast Asia: cases from the Philippines and Indonesia.
Dr. Takashi Tsuji, International Research Centre for Intangible Cultural
Heritage in the Asia-Pacific Region (IRCI), Osaka, 590-0802, Japan.

Oral presentation

11:50-12:00 : Yield and quality, color profile, and consumer acceptability of cheddar cheese
made from Holstein Friesian and buffalo milk
Tasrova Sultana, Department of Dairy Science
Bangladesh Agricultural University, Mymensingh, Bangladesh.

12:00-12:10 : Effect of carrot in fortifying block type buffalo milk processed cheese
Md. Al Imran, Department of Dairy Science
Bangladesh Agricultural University, Mymensingh, Bangladesh.

12:10-12:20 : Reorganization of a traditional buffalo processing practice by the
"meat seller caste" in Nepal
Dr. Kanako Nakagawa, Department of Sociology, Otemon Gakuin University
2-1-15 Nishiai Ibaraki Osaka, 5678502 Japan.

12:20-12:30 : Buffalo milk processing and marketing in the coastal areas of Bangladesh
Shmsuddin Illius, Bureau-in-Charge of Chittagong
The daily Independent, Chittagong, Bangladesh.

11.30 -12.30 : *Poster presentation*

12.40-14.00 : Lunch and prayer

PROGRAM

Scientific Session

Buffalo genomics and biotechnology

Chair	:	**Prof. Dr. Takashi Amano** Tokyo University of Agriculture, Tokyo, Japan.
Co-Chair	:	**Prof. Dr. Yi Zhang** Key Laboratory of Animal Genetics, reeding and Reproduction of Ministry of Agriculture and Rural Affairs, College of Animal Science and Technology China Agricultural University, Beijing 100193, China.
		Dr. Anonda Kumar Adhikary Director Artificial Insemination, Department of Livestock Services, Dhaka, Bangladesh.

14:00-14:15	:	*Keynote paper* Omics for understanding reproductive performance of buffalo bulls under heat-stress **Dr. Ranjit Singh Kataria,** ICAR- National Bureau of Animal Genetic Resources Karnal-132 001 (Haryana), India. *Oral presentation*
14:15-14:25	:	Complete genomic landscape reveals significant differentiation of phenotype and productivity in Asian water buffaloes (*Bubalus bubalis*) following recent and divergent selection **Jingfang Si,** Key Laboratory of Animal Genetics, Breeding and Reproduction of Ministry of Agriculture and Rural Affairs, College of Animal Science and Technology China Agricultural University, Beijing 100193, China.
14:25-14:35	:	Detection of polymorphisms in *FASN*, *DGAT1*, and *PPARGC1A* genes and their association with milk yield and composition traits in river buffalo of Bangladesh **Prof. Dr. Mohammad Shamsul Alam Bhuiyan,** Department of Animal Breeding and Genetics Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
14:35-14:45	:	Association between microsatellite markers, milk yield traits and milk composition in Murrah crossbreed buffalo **Dr. Neena Amatya Gorkhali,** National Animal Breeding and Genetics Research Centre Nepal Agricultural Research Council, Nepal.
14:45-14:55	:	Melatonin supplementation improves the quality of inferior oocytes and embryonic development by reducing oxidative stress **Dr. Prem Singh Yadav,** Animal Physiology and Reproduction Division ICAR-Central Institute for Research on Buffaloes, Hisar-125001, Haryana, India.
14:55-15:05	:	Genomic analysis reveals the association of *KIT* and *MITF* with white spotting in swamp buffaloes **Dongmei Dai,** State Key Laboratory of Animal Biotech Breeding, College of Animal Science and Technology, China Agricultural University, Beijing-100193, China.
14.00-15.15	:	*Poster presentation*
15.05-15.20	:	Tea Break

Scientific Session

Buffalo health and adaptability

Chair   : **Professor Dr. Md. Abdul Awal**
Dean, Faculty of Veterinary Science, Bangladesh Agricultural University, Mymensingh, Bangladesh

Co-Chair   : **Dr. Md. Bayzer Rahman**
Director Admin, Department of Livestock Services, Dhaka, Bangladesh.

Dr. Begum Shamsunnahar Ahmed
Director Extension, Department of Livestock Services, Dhaka, Bangladesh.

15:20-15:35 : *Keynote paper*
Optimizing buffalo health: Understanding the interplay with adaptability
Dr. Praveen Malik, CEO, Agrinnovate India Limited, New Delhi, India.
Oral presentation

15:35-15:45 : Challenges of Buffalo health in Asia: parasitic and microbial diseases, AMR zoonosis and food safety
Md. Hasanuzzaman Talukder, Department of Parasitology, Bangladesh Agricultural University, Bangladesh

15:45-15:55 : Comparative bacteriome diversity and composition across buffalo milk chain in Bangladesh:
insights into mammary health and microbial contamination
Dr. Shuvo Singha, Department of Medicine and Surgery, Chattogram Veterinary and
Animal Sciences University, Chattogram, Bangladesh.

15:55-16:05 : Molecular characterization and therapeutic insights into multidrug-resistant *Staphylococcus aureus*
strains isolated from bubaline reproductive tract
Professor Dr. Muhammad Ijaz, Department of Veterinary Medicine, University of Veterinary and
Animal Sciences, Lahore, Pakistan.

16:05-16:15 : Shotgun metagenomics for the identification of diarrheal pathogens in gut
microbiota of buffalo calves in Bangladesh
Mr. Khalilur Rahman, Department of Parasitology, Bangladesh Agricultural University, Bangladesh.

16:15-16:25 : Genetic variability of *Toxocara vitulorum* in buffaloes of Bangladesh
Dr. Hiranmoy Biswas, Department of Parasitology, Bangladesh Agricultural University, Bangladesh.

15.15-16.30 : *Poster presentation*

16.25-16.30 : Tea Break

Scientific Session

Buffalo management, economy and sociology

Chair   : **Prof. Dr. Md. Ruhul Amin**
Dean, Faculty of Animal Husbandry, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Co-Chair   : **Prof. Dr. Kazunobu Ikeya**
National Museum of Ethnology, Osaka, Japan.

Mr. Abdul Awal Mintoo
Lal Teer Livestock Development (BD) Limited Anchor, Dhaka-1205, Bangladesh.

16:30-16:45 : *Keynote paper*
The diversity of Buffalo breeding and its formative factors in Asia
Professor Dr. Kazunobu Ikeya, National Museum of Ethnology, Osaka, Japan
Oral presentation

16:45-17:00 : Pastoralism in the management of indigenous dairy buffaloes of Bangladesh
Prof. Md. Omar Faruque, Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Bangladesh.

17:00-17:10 : New technologies and digitalization in buffalo farming
Dr. Victoria Barile, Research Centre for Animal Production and Aquaculture, Rome, Italy.

17:10-17:20 : Reproductivity and productivity in relation to various factors of buffalo cows at barind area of Bangladesh
Professor Dr. Md. Jalal Uddin Sarder, Department of Veterinary and Animal Sciences, University of Rajshahi, Bangladesh.

17:20-17:30 : Agro-pastoral animal husbandry of buffalo: from settled rearing to transhumance in case of Nepalese mountain villages
Dr. Kazuyuki Watanabe, Hannan University, Japan.

17:30-17:40 : Buffalo production improvement attributes in reducing poverty at Bhola coastal area in Bangladesh
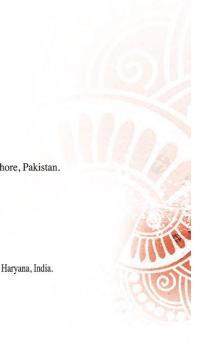**Md. Murshed Hasan Mustafa,** Department of Animal Science, Bangladesh Agricultural University, Bangladesh.

17:40-17:50 : Buffalo farming in Canada - an overview
Mr. Henry John Koskamp, Koskamp Family Farms Ltd., 4701 Line 29, Stratford, ON. N5A 6S4, Canada.

16.30-17.50 : *Poster presentation*

Country Report

Chair   : **Professor Antonio Borghese**
Secretary General, International Buffalo Federation, Rome, Italy.

Co-Chair   : **Professor Dr. Muhammad Ijaz**
Department of Veterinary medicine, University of Veterinary and Animal Sciences, Lahore, Pakistan.
Dr. Jiang-Hua Shang
Guangxi Buffalo Research Institute, Nanning- 530001, China.

09.00-10.00 : Special report on Recent advance of embryo transfer in buffalo
Dr. Liu Qingyou, Technical director, Royal Group Co., Ltd., No.65, Fengda Road
Gaoxin District, Nanning, Guangxi, China.

10.00-10:10 : Present status of buffalo in India and future trends
Dr. Ashok Kumar Balhara, Principal Scientist, Animal Physiology Division, ICAR-CIRB, Hisar, Haryana, India.

10:10-10:20 : Present status of buffalo in Nepal and future prospects
Dr. Neena Amatya Gorkhali, Director, National Animal Science Research Institute
Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal.

10:20-10:30 : Present status of buffalo in Bangladesh and future prospects
Prof. Dr. Md. Ruhul Amin, Professor, Department of Animal Science
Bangladesh Agricultural University, Mymensingh, Bangladesh.

10:30-10:40 : Present status of buffalo in Thailand and future prospects
Professor Dr. Skorn Koonawootrittriron, Department of Animal Science, Faculty of Agriculture
Kasetsart University, Bangkok 10900, Thailand.

10:40-10.50 : Present status of buffalo in China and future prospects
Professor Chengjian Yang, Guangxi Buffalo Research Institute, Nanning, 530001, China.

10.50-11.00 : Tea Break

Only for members

Asian Buffalo Association Assembly

Chair   : **Professor Dr. Md. Omar Faruque,** President, Asian Buffalo Association
Co-Chair   : **Dr. Inderjeet Singh,** Vice President, Asian Buffalo Association
Dr. Buminand Devkota, Immediate past president, Asian Buffalo Association
Moderator : **Dr. Ashok Kumar Balhara,** Secretary, Asian Buffalo Association

11.00-11.30 : Topics to be decided during congress; Recommendation of the congress

Prize distribution and closing ceremony

Chief guest : **Nilufa Akter,** Additional Secretary, MoFL, Dhaka, Bangladesh.
Special guest : **Dr. Farukul Islam,** General Manager, BRAC Artificial Insemination Enterprise
BRAC Centre, Dhaka, Bangladesh
Mr. Zakir Hossain Mohin, Grameen Jano Unnayan Sangtha, Charnoabad, Bhola, Bangladesh.
Chair   : **Professor Dr. Md. Omar Faruque,** President, Asian Buffalo Association
Moderator : **Dr. Hiranmoy Biswas,** Secretary, Organizing Committee

11.30-12.00 : *Prize distribution*
12.00-12.30 : Speech of Special guests
Speech of special guests
Speech of Chief guest
Vote of Thanks by **Dr. Ashok Kumar Balhara,** Secretary, Asian Buffalo Association
Closing word by **Professor Dr. Md. Omar Faruque,** President, Asian Buffalo Association
12.30-14.00 : Lunch and prayer
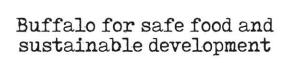14.00-17.00 : Visit to BLRI and DLS Establishments, Visit to national monument

CONTENT

11th ASIAN BUFFALO CONGRESS

THEMATIC PAPER

Buffalo for safe food and sustainable development

Tirtha Kumar Datta and Supriya Chhotaray

ICAR-Central Institute for Research on Buffaloes, Sirsa Road, Hisar, India.

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Abstract

The global food crisis has intensified, with nearly 282 million people facing acute food insecurity in 2023, driven by factors like extreme weather and inflation. This crisis is most severe in the Asia and Pacific region, where rising costs have made a healthy diet unaffordable for 232.8 million people. India, with around 200 million malnourished individuals, illustrates the growing demand for safe and nutritious food. Buffaloes have emerged as vital in combating hunger, contributing ~45% to India's milk production and significantly to meat production. Buffalo meat, known for its high protein and low-fat content, and buffalo milk, rich in essential nutrients, offer substantial health benefits. Sustainable farming practices, including efficient feed utilization and lower greenhouse gas emissions, further enhance buffaloes' role in food security. India's buffalo improvement programs over the past fifty years have significantly increased productivity through genetic advancements. Despite challenges such as smallholder farming constraints and low productivity, opportunities exist for expanding buffalo meat exports and value-added dairy products. Embracing precision dairy farming and advanced breeding programs can revolutionize India's dairy industry, enhancing global competitiveness and sustainability.

Keywords: Food insecurity, genetic improvement, milk and meat production, sustainable farming.
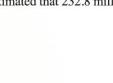
Food insecurity – The Hunger War

"True freedom is felt by a fuller stomach"

It was in 2006, when upon USDA's request the Committee on National Statistics (CNSTAT) of the National Academies Panel reviewed the status of food insecurity in USA and described the word "hunger" in their report as "...should refer to a potential consequence of food insecurity that, because of prolonged, involuntary lack of food, results in discomfort, illness, weakness, or pain that goes beyond the usual uneasy sensation." Hunger in the past has been more of an individualistic perception of health rather than a long-term global issue. According to the 2024 Global Report on Food Crisis (GRFC) released on April 24, 2024, nearly 282 million people in 59 countries faced high levels of acute food insecurity in 2023, with extreme weather being the second most significant factor contributing to the crisis.

Global food crisis

According to world bank group's latest report, domestic food price inflation remains high in low- and middle-income countries. As of the most recent update on April 25, 2024, 59.1% of low-income countries are experiencing inflation higher than 5% (an increase of 2.0 percentage points), 63% of lower-middle-income countries are facing similar inflation levels (a decrease of 0.8 percentage points), 31% of upper-middle-income countries are affected (a decrease of 2.0 percentage points), and 14.5% of high-income countries are experiencing inflation above 5% (an increase of 1.8 percentage points). In real terms, food price inflation surpassed overall inflation in 53% of the 166 countries where data is available. Half of the world's severe food insecurity is accounted by the Asia and Pacific region, with more women than men being food insecure. The new report, "Asia and the Pacific Regional Overview of Food Security and Nutrition 2023 – Statistics and Trends," reveals that the rising cost of a healthy diet is exacerbating food security issues. According to the latest statistics from the FAO and UN, the cost of a healthy diet increased by an average of 5.3 percent in purchasing power parity (PPP). It is estimated that 232.8 million people in the region are unable to afford a healthy diet.

India's rising demand for safe food

India is estimated to have around 200 million malnourished people, indicating extensive food insecurity. However, variations in methodologies used to assess food insecurity status introduce uncertainty regarding its severity and distribution across the country (McKay et al., 2023).

India's demand for safe food is rising significantly due to several factors, including increasing health awareness, urbanization, and changing dietary patterns. The food processing industry, which includes minimally processed and nutritionally enriched packaged foods, is growing rapidly to meet this demand. In 2023, the Indian food processing market was valued at INR 28,027.5 billion, with a projected CAGR of 8.8% from 2024 to 2032. This growth is driven by the need for healthier, convenient, and longer-lasting food products that align with modern consumer lifestyles (Deloitte United States) (IMARC).

Additionally, the organic food sector in India is witnessing substantial growth. The market, valued at US$ 1,582.2 million in 2023, is expected to grow at a CAGR of 21.19% from 2024 to 2032. This surge is fuelled by the increasing preference for organic foods, which are perceived as healthier and more natural than conventional options. The trend is further supported by the expanding availability of organic products through both online and offline retail channels (IMARC).

Overall, the combination of technological advancements in food processing and a shift towards organic and health-conscious consumption patterns highlights India's growing demand for safe and nutritious food products.

Buffaloes – Salvager in the Hunger battle

Presently buffalo alone contributes ~45% to the total milk production in India (BAHS, 2023). Buffaloes have emerged as vital players in the global fight against hunger, particularly in developing countries. According to the Food and Agriculture Organization (FAO), buffaloes contribute significantly to food security by providing milk, meat, and draught power, with over 97% of the world's buffalo population residing in Asia. India, for example, holds the largest buffalo population, with over 109 million head, accounting for nearly 57% of the global total (DAHD, Annual Report 2022-23). Buffalo milk production alone surpasses 90 million tonnes annually (NDDB Annual Report, 2022), providing essential nutrition to millions of people. Additionally, buffalo meat production, reaching around 4.2 million tonnes per year (Stasio and Brugiapaglia, 2021), plays a critical role in meeting the protein needs of growing populations. Buffaloes are also highly efficient in converting low-quality feed into high-quality products, thus optimizing the use of available resources in marginal environments and contributing to sustainable agricultural practices. Buffaloes have played a crucial role in India's small-holder dairy system, empowering millions of rural farmers to engage in dairy activities as a sustainable source of income. The adaptability of buffaloes to diverse agro-climatic conditions and their ability to thrive on low-quality forage have made them a preferred choice for small-scale dairy farmers. Enhancement of the productivity and efficiency of buffaloes through scientific breeding and improved management practices, can play an even more substantial role in combating hunger and ensuring food security worldwide.

Buffalo Bounty: Unveiling the Nutritional Treasures

Meat: Nutritional benefits and health implications for local diets

Since ancient times, meat has been a cornerstone of the human diet and continues to be so for many populations today. Although the quantity and source of meat consumed vary across countries and cultures, meat remains as an excellent protein source, as it contains all essential amino acids and provides several vital vitamins and minerals.

Buffalo meat, often termed "carabeef," is gaining recognition for its nutritional benefits and positive health implications for local diets. Rich in high-quality protein, buffalo meat provides all essential amino acids necessary for growth and maintenance of body tissues. It is also lower in fat and cholesterol compared to beef, making it a healthier alternative. According to the National Institute of Nutrition (NIN), 100 grams

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of buffalo meat contains approximately 20.7 grams of protein, 1.2 grams of fat, and only 1.9 milligrams of cholesterol. Additionally, buffalo meat is a good source of essential minerals such as iron, zinc, and phosphorus, which are crucial for various bodily functions, including immune support and energy metabolism. These nutritional advantages make buffalo meat as an excellent option for enhancing the dietary quality of populations, especially in regions where it is a staple protein source. Compared to beef, buffalo meat is leaner, contains less marbling, and boasts higher protein content, greater pigmentation, and higher dry matter content. Specifically, buffalo meat has 40% less cholesterol, 12 times less fat, 10% more minerals, 55% fewer calories, and 11% more protein. Due to its superior nutritional value over conventional beef and white meat like chicken, buffalo meat serves as an excellent source for producing high-quality processed products, such as smoked sausage. The significant amounts of zinc, vitamin B, and cholesterol found in buffalo meat can serve as an excellent nutrient supplement for pregnant women. (Rodrigues et al., 2024).

Milk: Nutritional content, dairy products, and their benefits for farmers

Buffalo milk has higher levels of total solids, crude protein, fat, calcium, and phosphorus, as well as a slightly higher lactose concentration. It is perfect for processing into dairy products with added value, such as cheese, due to its high total solids content. The health benefits of buffalo milk and the growing demands for value-added dairy products are the key drivers of buffalo milk market across the globe. Buffalo milk gets higher price as it contains more fat, protein and mineral content as compared to cow milk. In addition to it buffaloes have got good salvage value, and the value of the spent buffalo is very attractive for the dairy farmer. Buffalo milk contains a high amount of calcium, a mineral that is necessary for the development of bones. Moreover, it contains casein-derived peptides, which may promote bone health and reduce the likelihood of osteoporosis in women (Emakpor et al., 2024). Apart from it buffalo milk has many therapeutic properties and is beneficial for several health conditions where cow milk is not preferred.

Sustainable Farming Practices
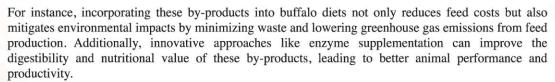
Greenhouse gas emissions: How buffalo farming compares with other livestock

Methane and nitrous oxide are the two main greenhouse gases originating from animal agriculture. Methane has an impact on global warming that is 28 times greater than that of carbon dioxide. It is primarily produced by intestinal fermentation and the storage of manure. The storage of manure and the application of both organic and inorganic fertilizers produce nitrous oxide, a chemical that has a 265-fold greater potential for global warming than carbon dioxide. One common measure for accounting for the possibility of global warming is the carbon dioxide equivalent (IPCC, 2013). Buffaloes produce 0.5 Giga Tonnes of carbon dioxide equivalent while Beef and Dairy cattle produce 1.8 and 1 Giga Tonnes of carbon dioxide equivalent, respectively (FAO, 2017). Many reports indicate that dairy buffaloes either emit more enteric methane (56 to 77 kilograms per animal per year, Thorpe, (2009)) than dairy cattle or are at par (55 kilograms per animal per year, IPCC) with cattle in methane emission. However, the pattern of GHG emission in meat purpose buffaloes differ from the dairy buffaloes. Buffaloes have the ability to fatten on a wide range of forages, including less digestible feeds that are difficult for other bovines to obtain energy from (FAO Regional Office for Asia and the Pacific, 2000). Brazilian buffaloes have significantly higher growth rate than cattle, reaching market size in 28 months in comparison to 38 months in cattle, while having a heavier slaughter weight, which reduces the per kilogram-meat methane emissions from buffalo from birth to slaughter (Sheikh et al., 2006). Also, draft buffaloes can be used to plough agricultural fields thereby reducing tractor and other machinery use to minimize the use of green-house gas emission intensive fuels.

Feed efficiency: Best practices for utilizing agricultural by-products and local resources

Utilizing agricultural by-products and local resources for feeding buffaloes enhances feed efficiency and sustainability in livestock production. Recent studies highlight the potential of by-products such as rice straw, wheat bran, and sugarcane bagasse, which are often abundant and underutilized in many regions.

For instance, incorporating these by-products into buffalo diets not only reduces feed costs but also mitigates environmental impacts by minimizing waste and lowering greenhouse gas emissions from feed production. Additionally, innovative approaches like enzyme supplementation can improve the digestibility and nutritional value of these by-products, leading to better animal performance and productivity.

Research has shown that using locally available feed resources can decrease reliance on imported feeds, which often involve significant environmental footprints due to transportation and intensive cultivation practices. This practice aligns with the principles of a circular economy by recycling agro-industrial residues into valuable livestock feed, thereby promoting sustainable agriculture and enhancing the resilience of local farming systems. These strategies are critical for improving the sustainability and efficiency of buffalo farming, contributing to a more environmentally friendly and economically viable livestock sector. Some study shows that Buffaloes can utilize the locally available resources better than cattle. Nitrogen excretion in urine in buffaloes was reported to be lower than cattle indicating better feed utilization efficiency of buffaloes. Buffaloes have better ability to recycle nitrogen in the rumen higher than cattle (Restitrisnani et al., 2019).

Buffalo improvement in India – a journey of 50 years

Over the past fifty years, buffaloes have been instrumental in shaping the trajectory of the Indian dairy industry, as evidenced by the remarkable trends in milk production. Since the 1970s, there has been a significant surge in milk output, with buffaloes contributing substantially to this growth. According to data from the Ministry of Fisheries, Animal Husbandry and Dairying, the milk production in India has witnessed an exponential rise from about 20 million metric tonnes in the 1970s to over 200 million metric tonnes in recent years, marking a tenfold increase. Buffalo is a triple utility breed and provides milk, meat, draught power alongside dung and hide. Murrah is one of the major dairy buffalo breeds in India, known for its high milk yield and fat%. Presently buffalo alone contributes ~45% to the total milk production in India (BAHS, 2023). Buffaloes have played a crucial role in India's small-holder dairy system, empowering millions of rural farmers to engage in dairy activities as a sustainable source of income. The adaptability of buffaloes to diverse agro-climatic conditions and their ability to thrive on low-quality forage have made them a preferred choice for small-scale dairy farmers. The histories of buffalo genetic improvement programs in India reflect a complex narrative of successes and failures intertwined with the country's agricultural landscape. India boasts a diverse population of buffaloes, with various indigenous breeds renowned for their milk production potential. The establishment of buffalo genetic improvement programs dates back several decades, with initiatives aimed at enhancing milk yield, reproductive efficiency, and disease resistance. One notable success story is the Murrah buffalo breed, which has been a focal point of genetic improvement efforts. Through selective breeding, artificial insemination, and embryo transfer techniques, Murrah buffaloes have demonstrated significant improvements in milk yield, with some individuals producing over 3,000 Liters of milk per lactation. Additionally, the establishment of elite breeding herds and the dissemination of superior genetics have contributed to the widespread adoption of improved Murrah buffaloes across the country.

India has emerged as one of the largest milk producers globally, however, its buffalo meat export industry has faced challenges in recent years. Stringent regulations, trade restrictions, and changing consumer preferences in key export markets have led to a decline in India's buffalo meat exports. The country has exported 1,175,869.13 MT (1.175 MMT) of buffalo meat products to the world for the worth of INR 25,648.10 Crores/ 3,194.70 USD Millions during the year 2022-23 (Source-DGCIS). India exported processed meat 331.57 MT worth 11.72 crores in 2022-23. However, there are still significant opportunities for the buffalo meat industry within India.

The ICAR-Central Institute for Research on Buffaloes (CIRB), since its inception in 1985, has been at the forefront of pioneering research endeavours aimed at bolstering the productivity, health, and genetic potential of indigenous buffalo breeds. By employing a holistic approach spanning breeding, nutrition, reproduction, and disease management, CIRB has catalysed a paradigm shift in the buffalo rearing sector,

heralding unprecedented levels of efficiency and sustainability. Through meticulous genetic evaluation and breeding programs, the institute has curated superior buffalo germplasm, notably championing high-yielding breeds such as Murrah and Nili-Ravi. The 305 days' milk yield of Murrah buffaloes maintained at the ICAR-CIRB unit, in 1991-92 was approximately 1552±60 kg. The genetic improvement through the progeny testing program brought upon a positive change of 84.36% improvement in the same in the year 2022-23. The average production level of each buffalo was also improved from 5.29 kg in 1992-93 to 8.52 kg in 2022-23 with a 61% increase. The program was also started for other breeds such as Nili-Ravi, Jaffrabadi, Surti, and Bhadawari at different centers. It was observed that in Nili-Ravi breed, the 305 days' milk yield in the year 2001-02 was ~1885 kg which improved to 2624 kg in the year 2022-23. In Jaffrabadi it was ~1813 kg in the year 2001-02 which increased to ~2524 kg in 2022-23. Similarly, in Bhadawari buffalo it improved from ~1029 kg in 2003-04 to ~1491 kg in 2022-23 (Annual Report 2022-23, Network Project on Buffalo Improvement).

Age at first calving (AFC) since inception in the 1991-92 was around 51 months in the Murrah herd maintained at ICAR-CIRB which has been reduced to 37 months with a decline of 27.45% with the help of systematic progeny testing program. AFC in the participating unit per buffalo decreased from 51 months in 1991-92 to 40 months in 2022-23 with a 22% reduction due to the systematic progeny testing program. Similarly, average service period reduced from 249 days in 1991-92 to 131 days at present with a 47% decline. Calving interval also reduced from 495 days in 1991-92 to 441 days in 2022-23 (Annual Report 2022-23, Network Project on Buffalo Improvement).
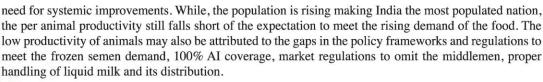
India has launched several initiatives to boost buffalo development through various organizations. The ICAR institutes like CIRB and NDRI focuses on genetic improvement, including successful cloning of superior buffalo bulls to enhance breeding efficiency and productivity, propagation of high yielding germplasm through OPU-IVF and other advanced reproductive biotechniques. The Rashtriya Gokul Mission, initiated by the Department of Animal Husbandry & Dairying, aims at the development and conservation of indigenous bovine breeds, including buffaloes, to improve milk production and productivity. National Dairy Development Board (NDDB) had implemented nation-wide animal identification through tagging and subsequent real time data recording system through INAPH. In 2021, NDDB collaborated with GCMMF to launch genomic selection for few indigenous dairy cattle and buffalo breeds. NDDB also released 'Buffchip' with Indian buffalo population representation. NDDB implements national dairy development programs, focusing on cooperative dairy farming, technical support, germplasm dissemination, genetic testing, genomic selection and financial assistance. BAIF a non-profit organization promotes sustainable rural development through integrated dairy farming practices and community empowerment. Additionally, collaborations with institutes like the CSIR-Institute of Genomics and Integrative Biology have enhanced research capabilities in genomic advancements and biotechnology for buffalo development.

Challenges and opportunities

The smallholder system in India presents significant challenges for buffalo production. These farmers typically operate on fragmented land holdings, which limits their capacity to achieve economies of scale. Traditional farming methods prevail, making the adoption of modern, efficient practices difficult. Additionally, infrastructure challenges, such as insufficient milk collection and processing facilities, hinder productivity and profitability. Furthermore, smallholder farmers often lack access to comprehensive extension services and market linkages, which are essential for improving production practices and ensuring sustainable development in buffalo farming.

India ranks first in milk production globally but is 93rd in productivity due to several factors. The country's dairy sector is dominated by smallholder farmers with limited access to advanced breeding technologies, quality feed, and veterinary services. Low genetic potential of indigenous breeds, coupled with inadequate management practices, also hinders productivity. Additionally, poor infrastructure for milk collection, processing, and distribution reduces efficiency. For example, despite producing over 22% of the world's milk, the average yield per cow is significantly lower than global standards, highlighting the

need for systemic improvements. While, the population is rising making India the most populated nation, the per animal productivity still falls short of the expectation to meet the rising demand of the food. The low productivity of animals may also be attributed to the gaps in the policy frameworks and regulations to meet the frozen semen demand, 100% AI coverage, market regulations to omit the middlemen, proper handling of liquid milk and its distribution.

With its large buffalo population of over 109 million animals, as per the Department of Animal Husbandry and Dairying, and growing demand for protein-rich foods domestically and internationally, there is potential for India to further develop its buffalo meat industry. By investing in infrastructure, adopting best practices in animal husbandry and food safety standards, and exploring new export markets, India can capitalize on the opportunities presented by its buffalo meat industry to enhance agricultural income and contribute to economic growth.

There is a huge market opportunity for buffalo meat, and its skin as leather in India as well as international market due to its non-association with any religious barriers. Buffaloes are inherently resistant to many diseases that have higher incidence in cattle which was also observed during the recent outbreak of Lumpy Skin Disease in India. This renders buffalo meat better suited to international markets although traceability issue still pesters Indian buffalo industry. However, NDDB has started SNP based parentage verification which can be used to trace the pedigree of the meat buffaloes. The research in this aspects needs to be strengthened to develop advanced traceability solutions.

Way forward

Buffalo milk has higher levels of total solids, crude protein, fat, calcium, and phosphorus, as well as a slightly higher lactose concentration. It is perfect for processing into dairy products with added value, such as cheese, due to its high total solids content. The health benefits of buffalo milk and the growing demands for value-added dairy products are the key drivers of buffalo milk market across the globe. Asia pacific region holds the baton to the rising demand due to the rising population especially millennials in this region. Compared to older age groups, millennials spend more and have more disposable income. Digital technology has given millennials more influence, and they are both more varied and demanding. The number of new product launches in the Asia Pacific has increased as a result of the region's growing number of market participants. This market forecast sheds light onto the opportunities for shifting the dairy industry towards the buffaloes. Amul stated that it will begin producing buffalo mozzarella in March 2021 and plans to invest Rs 200 crore in this business. Indian exports of mozzarella cheese may soon overtake those of Italy as the world's primary source of exports.

Value addition and packaging plays an important role in shaping the dairy industry's economy as well as promoting it in a global market. The net return from value addition is way too higher than the raw product such as milk. 1kg of buffalo milk is sold at INR 65/- (ICAR-CIRB milk price, 2024) while 1 kg fresh mozzarella cheese price varies form INR 800-900/- per kg. 1 kg mozzarella cheese can be prepared from 6 kg of buffalo milk as it has higher fat%. The net profit is almost doubled indicating that the value addition is in truest sense the pillar of doubling farmer's income through livestock rearing. Precision buffalo dairy farming holds the potential to revolutionize India's dairy industry, offering a pathway to enhanced productivity, efficiency, and global competitiveness. By leveraging advanced technologies such as data analytics, automation, and sensor-based monitoring systems, precision farming enables farmers to optimize every aspect of dairy production, from feed management and breeding practices to health monitoring and milk quality control. For instance, in countries like the Netherlands and the United States, precision dairy farming has been instrumental in achieving remarkable improvements in milk yield, reproductive efficiency, and overall herd health. According to a report by Research and Markets, the global precision dairy farming market is projected to reach USD 1.7 billion by 2026, underscoring the widespread adoption and immense potential of this technology. In the context of India, where buffalo farming plays a crucial role in dairy production, the application of precision farming techniques holds immense promise. By integrating precision technologies into buffalo dairy farming practices, Indian farmers can significantly enhance milk production efficiency, reduce input costs, and improve milk quality, thereby unlocking greater export opportunities. Moreover, precision farming enables farmers to meet stringent international standards for food safety and traceability, enhancing the competitiveness of Indian dairy products

in the global market. As India aims to position itself as a major player in the global dairy trade, the adoption of precision buffalo dairy farming represents a strategic imperative for the country's dairy industry to realize its full potential on the world stage.

A sustainable long term and advanced breeding program for improvement of buffaloes through the use of genomic selection and genetic testing of dairy bulls with higher accuracy and least biased estimates of breeding value necessitates a collaboration and data sharing through building the Nationwide consortium with all stake holders coming under a single umbrella. Development of national genetic evaluation system (NGES) and database first, followed by international evaluations of dairy and beef buffaloes (like INTERBULL), can help farmers make informed breeding decisions based on National and global dataset. Such initiatives need a collaborative effort through partnerships between universities, research institutions, and the agricultural industry to advance breeding technologies and share knowledge. Furthermore, the use of advanced reproductive technologies to improve conception rate and rate of germplasm dissemination such as AI, IVF, MOET, and sex-sorted semen though has been researched intensively in the last few decades yet a large-scale implementation awaits.

However, overall improvement of buffaloes across the nation depends hugely on the role of Government, its regulatory framework and infrastructure. The Government has to put more effort on promoting harmonization of regulations across countries to facilitate international trade and collaboration in buffalo genetics (BRAND Building of Buffalo), development of bull mother farms and A grade semen stations for faster dissemination of high yielding germplasm.

Over the past five decades, India's strides in buffalo improvement have been a testament to the nation's dedication to agricultural advancement. Through tireless efforts in breeding programs, adoption of modern management techniques, and leveraging technological innovations, India has witnessed a profound transformation in the quality and productivity of its buffalo population. This journey stands as a beacon of success, empowering farmers and bolstering the dairy sector's resilience. As we conclude this retrospective, it is clear that sustained commitment to research, innovation, and sustainable practices will remain imperative for furthering the trajectory of buffalo improvement in India, ensuring a prosperous future for both farmers and the nation's agricultural landscape.

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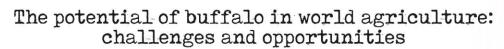
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THEMATIC PAPER

11th ASIAN BUFFALO CONGRESS

INVITED PAPER

The potential of buffalo in world agriculture: challenges and opportunities

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Abstract

Buffalo species (*Bubalus bubalis*) plays a pivotal role in the world economy, providing high nutraceutical value proteins of animal origin, fundamental for children's growth. Buffalo can convert fibre into energy and adapt to difficult environments, from cold climates to hot and humid ones, including wetlands, producing milk and meat respecting the sustainability of typical ecosystems, where the other ruminants cannot survive. Buffalo represents a unique opportunity to produce resources either for people in rural villages or for large farms in specific environments: marshlands (Iraq, Bangladesh, Indonesia, Amazonia, Colombia, Argentina) and humid savannah (Venezuela, Brazil, Paraguay), extensive pastures (Sumatra, Sri Lanka, Brazil, Argentina, Costa Rica, Bolivia, Mexico, Paraguay, Cuba, Australia), family farms (Thailand, Iran, Nepal, Bangladesh, Vietnam, Laos, Malaysia, Philippines, China, Egypt), also maintaining biodiversity, typical habitat, and cultural traditions.

Different challenges are posed by intensive farming (diffused in Italy, India, Pakistan, China and other American and Asian countries), which is accused of being responsible for a strong impact on climate change. However, different strategies have been studied and adopted to reduce the negative effects of intensive farming: livestock genetic improvement, sustainable agricultural practices, better utilization of local and feed resources (including by-products), manure management (including renewable energy production) and animal health and welfare improvement.

Keywords: Marshlands, humid savannah, family farms, extensive farming, intensive farm.
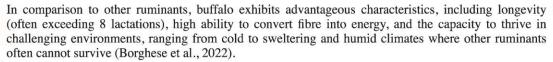
Introduction

The buffalo is a water animal that can survive under adverse weather conditions, thrives on rough food, and is responsible for maintaining the cleanliness of riverbeds and wetlands in areas where rice cultivation is prevalent. The buffalo can enter and work in the rice fields, particularly in the terraced areas, where mechanization is not a viable option and cattle can not survive.

The buffalo was domesticated along the Asian rivers, reaching East Asia in the first centuries, and migrated to the west, reaching the Tigris and Euphrates rivers and the Nile in Egypt. During the Middle Ages, the buffalo spread to Europe, while in America, the introduction of the buffalo occurred more than two centuries ago in Trinidad and Tobago, coinciding with the expansion of the English colonial empire. The abundance of land and natural pastures in South American countries created a unique farming environment where buffalo played an economic role in meat and milk production. Different breeds (Murrah, Italian Mediterranean, Jaffarabadi) were imported mainly from Europe and Asia and constituted the actual population. In Australia, the Northern Territory was the original entry point for the Swamp and Riverine buffalo from Asia as a food supplier into the new settlements established by the British in the 1800s. Domesticated buffalo were released free-range and spread to most floodplain areas.

The global buffalo population is estimated at 205.1 million in 2022, with 98% residing in Asia (Faostat, 2024). The species plays a strategic role in the global economy and society, with an annual production of 143.5 million tons of milk, 98.9% of the total produced in Asia, and 6.9 million tons of meat, 96.5 % produced in Asia (Table 1). The production of milk and meat from buffalo herds has increased significantly in recent years, driven by either population growth or genetic improvement. Between 2012 and 2022, milk yield increased by 27% and meat yield by 14% (Faostat, 2024).

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In comparison to other ruminants, buffalo exhibits advantageous characteristics, including longevity (often exceeding 8 lactations), high ability to convert fibre into energy, and the capacity to thrive in challenging environments, ranging from cold to sweltering and humid climates where other ruminants often cannot survive (Borghese et al., 2022).

Due to these characteristics, buffaloes can adapt to different farming systems. These include a) extensive management; b) marshlands and humid savannah; c) family farms; and d) intensive management.

Nevertheless, the adoption of optimal sustainable farming systems is not straightforward, as they may yield disparate outcomes. In some instances, they may favour biodiversity conservation and carbon sequestration, whereas, in others, they may prioritize production. For instance, grazing-based systems may exhibit superior environmental performance due to the reduced inputs required for production, although they necessitate more land. However, when land use options are incorporated into the assessment methodology, the results on environmental impacts may vary (Thomassen et al., 2008).

Extensive management

The extensive farming system is based on grazing pasture. A pasture is a system characterized by a mixed botanical composition, including plant communities in which grasses (Poaceae) are the dominant species, with dicotyledonous herbaceous species (Magnoliopsida) present in various quantities. Furthermore, in tropical zones, there are associations with legumes, weeds, trees, and shrubs, following the agroecological conditions of the climate, soil fertility, grazing pressure, pests, and livestock needs. Improved pastures are those sown with selected species (Motta-Delgado et al., 2019). In the view of Casimir and Rao (1998), a pasture is sustainable if there is a balance between the first trophic level (pastures), the consumers of the second trophic level (herbivores), and the consumers of the third trophic level (humans). This balance is maintained by ensuring that the population densities of both plants and herbivores remain relatively constant, while consumption does not exceed the primary productivity of plants. Similarly, a sustainable pasture should consider practices that balance production objectives with social values and ecological needs (Sherren et al., 2010).

Table 1. Buffalo population and production in the most representative countries in 2022.

	Head	Meat (T)	Milk (T)
Asia			
India	111,856,246	43,50,000	99,151,312
Pakistan	43,676,000	11,85,000	37,527,850
China	26,876,707	656,849	2,894,939
Nepal	5,132,931	194,090	1,464,802
Philippines	2,774,471	65,800	36,444,850
Vietnam	2,231,600	65,136	26,232
Myanmar	2,000,000	27,183	100,000
Bangladesh	1,508,000	6,972	326,850
Laos	1,208,634	17,200	---
Indonesia	1,170,209	21,710	90,522
Thailand	735,248	21,120	---
Africa			
Egypt	3,445,172[§]	197,278	1,508,000[§]
Americas			
Brazil	3,000,000*	---	---
Venezuela	2,800,000*	17,945	---
Colombia	485,141	8,378	23
Europe			
Italy	416,000	---	254,450
Bulgaria	20,320	16580***	15,280
Romania	17,900	14,100	---
Germany	11,680	---	---
Oceania			
Australia	180,000**	---	---
World	205,141,830	6,903,484	143,573,178

Data from Faostat (2024) except where differently stated.
* Patiño et al. (2023); ** estimated by Casanova (2019); ***2021 data; §2018 data

In grazing-based systems, forage intake, behaviour, and the performance of animals are commonly impeded by various factors. These include heat stress, which can impact animal health (Giro et al., 2019), and the low availability and nutritional value of forage, which can lead to reduced productivity and lower milk yields (de Oliveira et al., 2014). Additionally, high proportions of stems or dead plant matter may deter animals from foraging (Drescher et al., 2006). These and other environmental, vegetation, and management factors are strongly interrelated. Furthermore, pasture conditions may differ significantly between seasons and farming systems, including pure continuous grazing systems, agropastoral, and agro-silvopastoral systems. The presence of trees exerts a profound influence on the growth, morphology, and nutritional value of forage, affecting climatic conditions in a multitude of ways. These include shading, air temperature, relative humidity, and wind speed, as well as changes in soil water dynamics and nutrient cycling (Glatzle et al., 2021; Glatzle et al., 2024).

Extensive farming practices may reduce both environmental impact and costs while promoting animal welfare and quality product differentiation (Napolitano et al., 2013). Such practices may be conveniently employed for species well adapted to the environment, such as buffaloes, and non-productive animal categories, such as heifers (Sabia et al., 2018).

It is possible to conduct buffalo farming on natural pasture, which can ensure economic sustainability by reducing production costs. This is achieved by eliminating fixed costs (the barn) and variable costs (part of the feed is directly gathered from natural pasture by the animals). Furthermore, permanent grasslands play an essential role in climate stability, as they store a comparable amount of carbon to that stored by forests (Lal, 2004).

Additionally, the manure produced by grazing animals has the potential to mitigate the risk of desertification, thereby improving soil functionality in terms of structure, organic matter content, and resilience to erosion by wind or water. When handling and spreading manure, no significant amount of methane is added when spread directly on pastures and fields (Bernués et al., 2011).

Although this system requires greater land use, it increases animal welfare and livestock sustainability and promotes landscape ecology and biodiversity conservation. However, grazing should be properly streamlined to avoid generally claimed excessive ecological damage caused by buffalo overgrazing, trampling, soil compaction, and overuse of water sources (Hoogesteijn and Hoogesteijn 2008). The causes of these impacts can be ascribed to buffalo thermoregulation habits, including wallowing in the mud, especially in periods and areas characterized by hot climates (Mora-Medina et al., 2018).

Sabia et al. (2018) found that heifer-free-ranging reduced water consumption and polluting agents in the atmosphere and water. At the category level, they observed a reduction of the impact of climate change (9%), terrestrial acidification (10%), marine eutrophication (6%), and water depletion (11%), whereas agriculture land occupation was 7% higher.

The availability of great extension of land, rich in pasture, in some areas in Asia (Sumatra, Sri Lanka) Australia, and much more in Central and South America (Brazil, Argentina, Costa Rica, Bolivia, Mexico, Paraguay, Cuba) represented a good opportunity to realize a new economy based on grazing.

Wetlands

This type of farming is present in different regions of the world, including marshlands in Iraq, Bangladesh, and Indonesia, as well as humid savannahs in Venezuela, Brazil, Argentina, Paraguay, and Colombia.

The estimated area of the world's marshlands is between 7 and 9 million km², representing a significant proportion of the planet's terrestrial surface (Mitsch, 2005).

The marsh is a wetland form saturated in water and composed mainly of grasses and reeds found near the fringes of lakes and streams, serving as a transitional area between land and aquatic ecosystems. Marshland ecosystems are distinguished by their hydrology, physiochemical environment, and biota, and play an essential role in the evolution of life on earth. Historical evidence demonstrates that these ecosystems have been vital for the survival of human communities. In the context of livestock

management in marshland areas, several recommendations can be put in place to maintain water quality. These include the avoidance of excreta and feces accumulation in bodies of water, as well as the prohibition of herbicides' use in bodies of water. Additionally, the reduction of landscape modifications that affect the hydrological regime and water quality, such as the construction of dams or canals, is of utmost importance. Furthermore, the rotation of livestock distribution areas can help minimize nutrient input, while the rational use of veterinary products can help mitigate the impact of these products on the environment and water quality.

Among the wetlands savannah is the terrestrial biome, mainly subtropical and tropical, found in numerous transition zones between rainforest and desert or steppe mainly in Central and South America, Central Africa, India, Indochina and Australia.

The vegetation is predominantly shrubs and trees, arranged in a way that does not result in the formation of a closed canopy. Tropical and subtropical savannah distribution is largely determined by rainfall scarcity and marked seasonality. Rainfall of less than 1000-2000 mm per year, insufficient for developing trees and shrubs, results in grassland formation. As one progresses towards more humid latitudes, specifically towards the equator, one observes the emergence of shrub vegetation (up to 3000 mm). Grass tends to grow rapidly in wet months, whereas, during the dry season, desiccates.

It has been demonstrated that tropical savannas have evolved in conjunction with grazing, resulting in modifications to the structural and functional components of the ecosystem (Schuman et al., 1999). This is achieved through vegetation clipping, trampling on soil, dunging, and urination (Pineiro et al., 2010). Soil properties are known to change due to compaction, which in turn affects soil organic carbon and nitrogen levels (Schuman et al. 1999; Pineiro et al. 2010). The impact of livestock trampling on soil properties is further intensified when current levels of grazing in most savannas are left unchecked (Holdo and Mack 2014; Arnhold et al. 2015; Brearly and Thomas 2015).

Grazing during drought will induce soil and plant water stress that will destabilize soil C and N contents, therefore likely to affect other soil properties and plant physiological processes. Increased rainfall beyond ambient is highly unlikely to affect most soil properties due to its minimal effect on soil moisture (Ondier et al., 2019).

Given its distinctive anatomical and physiological attributes, the water buffalo exhibits an aptitude for grazing in wetlands. In comparison to cows and other livestock, the water buffalo displays enhanced capabilities in navigating wet and muddy terrain. Furthermore, it is uniquely suited for the efficient harvesting of biomass and cleansing of riverbeds, thereby facilitating the regeneration of aquatic plants, seeds, and small organisms which serve as sustenance for aquatic birds. It is evident that the presence of the water buffalo significantly enhances the biodiversity and abundance of wetland species. In these environmental conditions, the buffalo may produce milk and meat with high nutritional value, thereby making the wetland farming system a compelling model for habitat conservation and a strategy against climate change (Barboza Jiménez, 2016).

Family farm
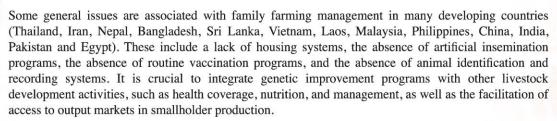
The International Steering Committee for the 2014 (IYFF) defines family farming as "a means of organizing agricultural, forestry, fisheries, pastoral, and aquaculture production which is managed and operated by a family and predominantly reliant on family labour, including both women's and men's." The committee further states that "the family and the farm are linked, co-evolve, and combine economic, environmental, social, and cultural functions" (FAO, 2013).

Family farms have a significant impact on sustainable development, as well as on the well-being of people and the planet. Indeed, it is estimated that over 90% of farms are run by an individual or a family, with women providing almost 50% of farm labour and holding less than 15% of farmland. Furthermore, family farms are responsible for over 80% of the world's food production, managing around 70-80% of farmland worldwide. In summary, family farms facilitate employment, stimulate rural economies, prevent depopulation, and support the areas.

Some general issues are associated with family farming management in many developing countries (Thailand, Iran, Nepal, Bangladesh, Sri Lanka, Vietnam, Laos, Malaysia, Philippines, China, India, Pakistan and Egypt). These include a lack of housing systems, the absence of artificial insemination programs, the absence of routine vaccination programs, and the absence of animal identification and recording systems. It is crucial to integrate genetic improvement programs with other livestock development activities, such as health coverage, nutrition, and management, as well as the facilitation of access to output markets in smallholder production.

Family farms perform a multitude of functions beyond the mere production of food. They simultaneously fulfil environmental, social and cultural roles, and help to mitigate the risks of biodiversity loss, preserving landscape and maintaining community and cultural heritage. Furthermore, they possess the knowledge to produce nutritious and culturally appropriate food as part of local traditions (World Family Forum. 2019)

Intensive farming

In its most basic definition, agricultural intensification can be understood as an increase in the production of agricultural commodities per unit of inputs, such as labour, land use, fertilizers, time, feed, animals, or capital (Kenmore et al., 2004).

Given that land is the ultimate limiting factor for agricultural production, it can be observed that most studies defining agricultural intensification focus on the increased output per unit area of land (Donald et al., 2001).

The primary drivers of livestock intensification are population growth, an increase in gross domestic product (GDP), urbanization and the globalization of markets, all of which have collectively elevated consumer demand for animal products. This has led to a shift in focus within the livestock sector towards product intensification, accompanied by changes in branch industries and transportation, particularly in developed and developing countries (Italy, India, Pakistan, and China). The intensification of livestock production per cow was primarily driven by improvements in feed conversion efficiency, whereas the intensification per hectare was largely attributable to enhanced productivity per cow, reduced culling and replacement rates, and increased forage and crop yields per hectare (Crosson et al., 2011).

However, the expansion of dairy systems inevitably results in heightened environmental impacts per hectare due to the increased incorporation of maize silage and concentrate feed in the diet, which necessitates greater input utilization. Consequently, it is challenging to reconcile environmental impacts with productivity in dairy systems (Salou et al., 2017).

The handling of buffaloes reared in intensive systems is comparable to that of cattle, except for the introduction of new stressors. These include the artificial rearing of calves and a reduction in space. Restrictions on space can affect health, social behaviour, and heat dissipation, particularly when there is no access to pasture and water for wallowing (Napolitano et al., 2013).
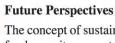
For these reasons, it is of the utmost importance that the welfare of buffaloes in intensive systems can be guaranteed. This will enable them to display their species-specific behaviours naturally, which could potentially have a positive impact on the quality of the final product. Furthermore, the sustainability and the welfare of the animals could also affect consumer liking (Mota-Rojas et al., 2019).

Some advanced techniques such as smart farming are being developed to increase the sustainability of intensive management. The smart farming system is a new concept in the agricultural field and refers to managing farms using technologies like sensors, software, data analysis, communication systems, etc. that enable farmers to give plants/animals the precise treatment that they need. Regarding livestock, most of these technologies are utilized in the dairy cattle sector, where the use of automated and robotic devices is increasing rapidly.

In buffalo, ear tag sensor systems for recording activity, resting, rumination, and temperature at ear level are tested to get information on health, nutrition, and reproduction (Meo Zilio et al., 2022).

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Future Perspectives

The concept of sustainable livestock farming must consider several economic and social factors, including food security, poverty alleviation, mitigation strategies, and social and cultural value preservation. This can only be achieved by implementing policy initiatives, which involve all stakeholders in the supply chain. To address the impacts of climate change, it is essential to adopt sustainable agricultural practices, utilize local feed resources more effectively, and enhance the nutritional value of the produced food, considering land and water scarcity.

The genetic diversity and adaptability of buffalo to different environments, including cold climates, hot humid conditions and wetlands where other ruminants cannot thrive, could contribute to the achievement of some of the Sustainable Development Goals set out in Agenda 2030.

Pastures are anthropogenic ecosystems that offer low-cost food resources, primarily for the feeding of ruminants, with buffalo playing a significant role in the production and livelihoods of many rural communities. The intensification of buffalo meat and milk production on pasture has been demonstrated to be sustainable when rational grazing practices are employed (Bertoni et al., 2021; Singh et al., 2023).

In the future, crop-livestock-forest integration systems, including silvopastoral systems, will become increasingly relevant and help to reclaim agricultural areas that have been altered by inappropriate previous use. Such practices could potentially enhance the value of the land, facilitating more efficient nutrient cycling. Alternatively, they could improve animal welfare, either through natural shading or by acting as a carbon sink.

Due to its anatomical and physiological characteristics, the buffalo is the only ruminant that can be reared in wetlands, and it can produce milk and meat of high nutritional value. This makes the marshland farming system an interesting model for habitat conservation. It also increases biodiversity, which is of benefit to the local population.

In Southeast Asia in particular, the family farming system has a pivotal role in sustaining people's livelihoods. This is due to the local buffalo breeds, some of which are endangered. It is therefore imperative for these breeds to be maintained, as they are the most adapted to low-input production systems and a specific environment, producing food with unique properties.

Future advancements in smart technologies hold great promise especially in intensive production systems, adapting to individual animals' needs will help reduce the inputs and improve animal welfare.

The livestock production systems are strictly linked to sustainability, welfare, and quality of products and the new technologies and education will play a pivotal role in facing the challenges of climate change.

Acknowledgment

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Buffalo for sustainable dairying

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Buffalo is native to the Northern river basin plains of India and Pakistan, where the best buffalo breeds of the world have evolved and produce high quality milk that is not only more suitable for Indian sweets but also saves on the cost of transportation and processing as it contains 6 to 7 per cent unit less water content as compared to exotic cow milk. In other terms we can also say that the availability of total milk solids, including fat, in Buffalo milk is over 40% higher than HF cow milk. Buffalos are resistance to several endemic diseases as well as to emerging diseases as witnessed during last year for LSD out-break. Buffalo have much higher longevity and normally gives 10 to 15 lactations in its life time. With routine management, the incidence of mastitis is much lower as compared to HF cows. Hoof disorders are unheard of. Even the surplus animals which have outlived their productive life also fetch handsome amount to the owners through producing good quality meat. Therefore, it is no surprise that there is no stray buffalo on the streets.
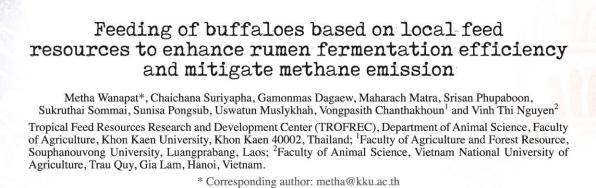
Buffalo thrives even in the adverse climatic condition with little management intervention. At the same time Buffaloes are often blamed for certain inadequacies like late maturity, long inter caving periods, low lactation yields, high calf motility and strong mothering instinct with somewhat problematic milk let down. However, recent experiences reflect round-the-year breeding ability of buffaloes when given appropriate balanced diets and management practices, particularly heat stress alleviation. Improved buffalo germplasm is now becoming available through government and private breeders and frozen semen centres. In case of Murrah buffaloes, the states like Andhra Pradesh have made great strides in Buffalo Improvement with favorable policy framework put in place. Regular organization of National Livestock and milking Championship and incentivizing superior animals' owners can make quicker progress in buffalo development. The major shortcoming in the past has been deficiencies in proper bull selection thus compromising on genetic gain in future generations. Now with INAPH recording of production data, proper CMU accredited frozen semen production and incorporation of genomic breeding value have made bull selection more scientific and authentic.

The benefit of IVF-ETT has been percolating slowly to buffalo breeding but is not as efficient as for cattle. Sexed semen production for buffaloes has been initiated already and needs to be incorporated in progeny testing programs for faster and cheaper progeny testing. The private sector is making inroads into application of these technologies in buffalo development. Breed multiplication farms being supported by the Govt. of India are promising for conservation and propagation of superior buffaloes. Mechanization, including machine milking, are becoming a norm in larger buffalo farms. The application of artificial intelligence is increasingly visible and helping various farming operations including dairying. However, in dairy farming, these applications are developed for dairy cattle, which are usually not fully applicable to dairy buffaloes due to different behavior and physiology. So, in order to develop such tools to aid in precision buffalo dairy farming, which will not only economize the feeding and management but also help realize the optimal output, such technologies need to be invested into.

In peri-urban dairies good quality freshly calved animals are housed or purchased from rural areas. The calves (both males and females) are neglected to die due to consideration of milk costs, which results in loss of superior germplasm. There is an urgent need to retain the heifers to ensure supply of replacement heifers to farmers. Therefore, there is need to establish buffalo nurseries that will have advantages of preservation of quality germ plasm, more intensive genetic selection, lowering of age at first calving by 8-9 months, employment generation to rural youth and enhanced income.

Overall there is need to embark upon a mega-program on Rastriya Buffalo Mission, on the lines of Rastriya Gokul Mission, so as to make the best advantage of this virtuous species native to Indian subcontinent and a strength of our dairying.
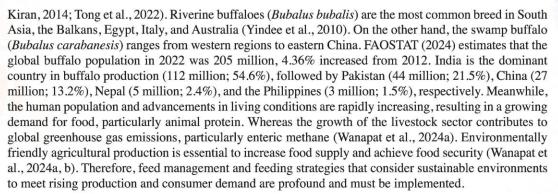
Feeding of buffaloes based on local feed resources to enhance rumen fermentation efficiency and mitigate methane emission

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Abstract

Buffaloes are one of the important ruminants contributing to the food security in forms of meat and milk, as well as their by-products such as skin, horn and manure. The buffalo's meat, milk and their products have been revealed with high nutritious values, especially the protein and amino acids profiles and some essential bioactive compounds for health and well-being. Above all, the buffaloes have been shown to be the smart ruminant in converting the high fibrous feeds, in particular agricultural biomass and industrial by-products, by enhancing the rumen fermentation end-products via the anaerobic Embden Meyerhof Parnas pathway while mitigating rumen methane emission. Concerning the rumen microbiomes of buffaloes, it has been reported that they were highly diversified and relatively higher-abundant as compared to those of cattle, leading to enhanced total volatile fatty acids (VFAs), microbial protein synthesis and lower methane production. With current advanced analysis using Next-Generation Sequencing (NGS) of rumen microbiomes offered more insightful understanding of their ability to degrade more fibrous feeds especially the agricultural crop-residues, low-quality roughages and some plastic materials. Relative abundances of the predominant bacterial population have been found under the phyla; Firmicutes and Bacteroidetes such as *Ruminococcus albus*, *Ruminococcus flavefeciens*, *Fibrobacter succinogenes*, *Prevotella ruminocola*, and *Pseudomonas aeruginosa*. Furthermore, current experiments have revealed predominant *P. aeruginosa* in the rumen digesta of swamp buffaloes, capable of degrading fibrous feeds as well as plastic wastes. Since, enormous agricultural biomass have been commonly available globally, as a result of the crop cultivation especially those of straws, stovers, vines and tops, as well as the industrial by-products such as pineapple peels, cassava pulp, sugar-cane bagasse, sorghum residues etc. Simple and practical pre-treatment such as the urea-lime (2+2% U-lime) has been successfully exploited to enhance the crude protein content and digestibility of nutrients, while mitigating the rumen methane production. The U-lime treated rice straw and supplementation of phytonutrient fruit-peel pellets (MARABAC) have been found to be significantly beneficial to improve the rumen fermentation in the ruminants. Therefore, dietary manipulation based on the pre-treatment of the fibrous feeds and supplementation of phytonutrient pellets should be more intervened on-farm to improve ruminant productivity. Furthermore, the feeding interventions based on the use of locally available resources should be extensively exploited focusing on the hands-on establishment (E), development (D), utilization (U), and sustainability (S) (EDUS), for all engaged stakeholders of farm level up to the industrial platform. Hence, the buffalo production scenario would be economically-viable, technically feasible and practically-sustainable.

Keywords: Agricultural biomass, phytonutrient, methanogenesis, ruminal degradability, *Bubalus bubalis*, ruminant.

Introduction

Buffaloes, scientifically known as *Bubalus bubalis*, are sizable ruminant creatures that hold significant value in the lives of many people. They serve as a crucial source of milk, meat, draught power, transportation, and on-farm manure in many Asian countries (Wanapat and Kang, 2013; Naveena and

Kiran, 2014; Tong et al., 2022). Riverine buffaloes (*Bubalus bubalis*) are the most common breed in South Asia, the Balkans, Egypt, Italy, and Australia (Yindee et al., 2010). On the other hand, the swamp buffalo (*Bubalus carabanesis*) ranges from western regions to eastern China. FAOSTAT (2024) estimates that the global buffalo population in 2022 was 205 million, 4.36% increased from 2012. India is the dominant country in buffalo production (112 million; 54.6%), followed by Pakistan (44 million; 21.5%), China (27 million; 13.2%), Nepal (5 million; 2.4%), and the Philippines (3 million; 1.5%), respectively. Meanwhile, the human population and advancements in living conditions are rapidly increasing, resulting in a growing demand for food, particularly animal protein. Whereas the growth of the livestock sector contributes to global greenhouse gas emissions, particularly enteric methane (Wanapat et al., 2024a). Environmentally friendly agricultural production is essential to increase food supply and achieve food security (Wanapat et al., 2024a, b). Therefore, feed management and feeding strategies that consider sustainable environments to meet rising production and consumer demand are profound and must be implemented.

Given the current situation, there is a need for increased animal production while reducing production costs. Wanapat and Rowlinson (2007) stated that seasonal feed resources are necessary for swamp buffaloes and riverine buffaloes, to sustain efficient production in small-holder farming settings. Four primary categories of feeds are potentially available for use on small mixed farms in Asia: foliage (native and enhanced grasses, legumes, and fodder trees), crop residues, agro-industrial by-products, and non-conventional feed resources (Wanapat and Rowlinson, 2007). Many researchers have been working to enhance the nutritive value of agricultural crop-residues for buffalo production, such as urea-treated straw (Hart and Wanapat, 1992), various plant protein sources (Foiklang et al., 2011), ground corn cob (Wanapat et al., 2012), corn fodder (Bakshi et al., 2017), rice gluten meal (Mahesh and Thakur, 2018), sugarcane top (Rakhmani and Puastuti, 2024), etc. This phenomenon has the potential to reduce the cost of animal feeding while simultaneously enhancing the economic efficiency of animal production. In addition, the use of feed additives to inhibit methanogenesis is necessary to mitigate methane production in the rumen through feeding management (Wanapat et al., 2024a, b). Wanapat and Kang (2013) reported that the use of plants, roughage and concentrate utilization, feed additives, and containing secondary compounds (condensed tannins and saponins) and oils plants to reduce methane production in the rumen. Effective feed management in buffalo farming could be sustainable by increasing productivity and lowering feed costs, which would be beneficial for farmers and the environment. This review paper discusses the feeding of buffaloes based on local feed resources to enhance rumen fermentation efficiency and mitigate methane emissions, as well as demonstrating the potential use of microorganisms in the buffalo rumen to manipulate rumen ecology and to reduce negative impacts on environment.

Rumen microbiomes and enteric fermentation efficiency of buffaloes

The rumen microbiomes of buffaloes constitute a diverse and intricate community of microorganisms crucial for the digestion and fermentation of consumed feed. This microbial community comprises of the bacteria population (gram negative bacteria species) 10^{10-11} cells/ml, an archaea population (methanogens) 10^{8-9} cells/ml, fungi (genera Piromyces, Anaeromyces, Cyllamyces, Neocallimastix, and Orpionmyces) of 10^{3-4} cells/ml, and protozoa (genus Entodinium) of 10^{5-6} cells/ml, each playing distinct roles in rumen fermentation (Newbold and Ramos-Morales, 2020; Keum et al., 2024). Rumen microbial populations play a pivotal role in the enzymatic degradation and transformation of complex plant polysaccharides into energy, thereby providing a substantial portion, approximately 70%, of the daily energy needs of the animal and contributing 60–85% of the amino acids reaching the small intestine. The rumen microbiota has developed a wide range of enzymes with diverse functions, facilitating the breakdown of plant cell wall polysaccharides polysaccharides (Gharechahi et al., 2023). Tong et al. (2022) have revealed comprehensive data on microbiomes in the rumen of swamp buffaloes.

Through synergistic interactions, these microorganisms degrade complex carbohydrates like cellulose and hemicellulose into simpler compounds. This process yields volatile fatty acids (VFAs), ammonia nitrogen (utilized for microbial protein synthesis), and methane as the primary fermentation end-products. Microbial degradation of all feed types, particularly roughages, occurs via cellulolytic bacteria utilizing

the Embden Meyerhof Parnas pathway, resulting in the synthesis of short-chain VFAs such as acetate (C2), propionate (C3), butyrate (C4), valerate (C5), and caproate (C6). These VFAs serve as major energy sources for ruminants (Wanapat et al., 2013a; Huws et al., 2018).

In contrast to other ruminants, such as cattle, buffaloes exhibit superior utilization of low-quality roughage, as well as agricultural and industrial by-products rich in lignocellulosic materials. This enables buffaloes to thrive on locally available crop residues and enhances their resistance to prevailing diseases (Rehman et al., 2021; L. Zhang et al., 2020). While the precise mechanism behind buffaloes' heightened digestive capacity compared to cattle remains incompletely understood, disparities in rumen ecology likely play a pivotal role (Chanthakhoun et al., 2012). Consequently, buffaloes demonstrate elevated nutrient digestibility across various components including dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) compared to cattle. Moreover, buffaloes exhibit a faster liquid outflow rate from the rumen, potentially resulting in reduced total rumen ciliate protozoal populations (Flachowsky, 2004; Li et al., 2022). Moreover, methane-producing archaea are prevalent within the rumen microbiota, contributing to methane emissions, a significant environmental concern. Understanding the composition and function of rumen microbiomes in buffaloes holds paramount importance for optimizing their nutrition, enhancing feed efficiency, and addressing methane emissions to promote sustainable livestock production. Various factors, including diet, age, breed, host, and geographical location, exert direct or indirect influences on rumen microbial populations (Furman et al., 2020; Guo et al., 2020). Understanding the rumen ecology of ruminants, especially the rumen microbes, their distribution, metabolomics, nutrigenomics, proteomics, etc., will enhance the insightful data for implementation (Russell and Rychlik, 2001; Seshadri et al., 2018).

Potential shifting of fermentative carbon and hydrogen from methanogenesis to propionate randomizing pathway Usually, ruminal microbes have the ability to ferment low-quality feedstuffs, particularly agricultural biomass, which is rich in cellulose and fiber contents (Wanapat, 2023). This process enables them to transform plant structural components that are not immediately usable by monogastric animals into meat and milk products (Wang et al., 2018). Simultaneously, the hydrolysis of complex molecules by ruminal microbes breaks down or degrades dietary structural carbohydrates (fibrous feeds) and nonstructural carbohydrates (starch), resulting in the production of volatile fatty acids (VFA), hydrogen (H_2), and carbon dioxide (CO_2) (Wanapat et al., 2024a; Wang et al., 2018). The reoxidation process in the rumen introduces H_2 with the involvement of various cofactors such as FADH, NADPH, and NADH (Wanapat et al., 2024a). This dynamic process significantly impacts the fermentative metabolism and acetogenic bacteria in the rumen through interspecies H_2 transfer (Stams and Plugge, 2009). Meanwhile, methanogenic archaea utilize CO_2 and H_2 produced in the rumen as primary sources for methanogenesis (Ellis et al., 2008). Methanogenic archaea employ distinct pathways for methane synthesis, with the most common being the CO_2-reducing (hydrogenotrophic) and hydrogen-dependent mechanisms, which require the use of the methyl-coenzyme M reductase (MCR) gene in the process (Berghuis et al., 2019; Cavicchioli, 2007). In addition, the majority of methanogens can utilize formate, which is generated during the pyruvate-acetyl-CoA formation process, as a hydrogen ion (H^+) donor for ruminal methanogenesis (Schauer and Ferry, 1980). The unused formate is rapidly converted to CO_2 and H_2. The rumen methane (CH_4) can also be produced through the methylotrophic pathway using methyl groups and, to a lesser extent, from acetate (Huws et al., 2018). Therefore, reducing methanogenesis can lead to the release of H_2 molecules, which can be used in pathways that produce end products of rumen fermentation, such as VFA, with a particular emphasis on propionic acid (C3) (Wanapat et al., 2024a; Wang et al., 2018), especially when fed a high-concentrate diet. The C3, the primary glucose precursor that serves as an extra source of energy for ruminants, is an alternative H^+ sink to CH_4 (Beauchemin et al., 2020). This leads to a negative relationship between the synthesis of C3 and CH_4 emissions, as C3 and methanogens compete for the same hydrogen resources (Wanapat et al., 2024a; Beauchemin et al., 2020; Wang et al., 2018). Consequently, it is advantageous to optimize the roughage-to-concentrate (R:C) ratio for ruminats with substantial requirements for glucogenic precursors. This optimization would serve as a beneficial H^+ sink

to enhance methanogenesis-inhibited rumen fermentation and lower CH_4 production (Ungerfeld and Kohn, 2006; Wanapat et al., 2013ab; Beauchemin et al., 2020).

Rumen degradability of plastic by *P. aeruginosa* in buffalo rumen and potential application

The environment frequently contains plastic waste, which takes generations to fully decompose. Plastic waste accumulations have a detrimental effect on both terrestrial and marine habitats, leading to significant health consequences. Marine ecosystems are in danger because pieces of polyethylene (PE), polystyrene (PS), and polyethylene terephthalate (PET) polymers are floating around in water (Webb et al., 2012). Consequently, researchers have identified biodegradation as an environmentally beneficial method to address this significant issue. Scientific communities around the world are actively researching how to develop highly effective microbial species capable of digesting plastic. PE biodegradation refers to the process of converting organic polymers into gasses such as CO_2 and CH_4 or into short-chain oligomers (Shilpa et al., 2022). The goal of this review section was to find out how ruminal microbiomes, especially those found in the rumen of buffaloes, break down plastic. However, there is a lack of evidence and research results in this area. Many factors, including pH, temperature, type of plastic breaking down, and the composition of the consortium or single strain, influence the process. Numerous studies in the literature suggested that bacteria, particularly *Pseudomonas*, used in the bio-ecosystem process can proliferate in two primary ways: as free cells and as biofilm formations. Biofilms are clusters of bacteria that adhere to living or non-living surfaces, encircled by extracellular polymeric substances (Ganesan et al., 2022). Recently, Wanapat et al. (2024, unpublished data) indicated that the population and density of *Pseudomonas* sp. in the rumen of swamp buffaloes were higher than those in the rumen of Thai native cattle. This was found using a metagenomic approach and next-generation sequencing. Additionally, researchers conducted a series of experiments on buffalo rumen to isolate and screen the *Pseudomonas aeruginosa* strain KKU-LDPE4, which is capable of degrading plastic sheets (LDPE) and cellulose, with the aim of obtaining a pure culture of strains with these degrading abilities. In other research, Quartinello et al. (2021) looked at the rumen contents of cattle (*Bos taurus*) to find enzymes that break down synthetic polyester. This investigation is motivated by the presence of natural plant polyesters in ruminants' diets. The researchers tested rumen fluid with model substrates and found hydrolytic activity on p-NP-esters containing four to eight carbon atoms. More terephthalic acid is released from poly (butylene adipate-co-terephthalate; PBAT) in rumen fluid than from poly (ethylene terephthalate; PET). An investigation of the rumen microbiome using shotgun metagenomics showed the actual proportions of all domains of life, demonstrating the prevalence of bacteria (98%), followed by eukaryotes (1%), and finally archaea. This result confirms the previously demonstrated the presence of polyester hydrolysis activity in abundant taxa, including *Pseudomonas*. Several reports (Quartinello et al., 2021; Ribitsch et al., 2013) have shown that *Pseudomonas* sp., found in the rumen of cattle, can degrade various kinds of plastic (LDPE, PET, and PBAT). In our study, we have identified *Pseudomonas* sp. from ruminal fluid of buffalo and demonstrated its ability to degrade polyester (Fig. 1).

Sources of agricultural biomass and treatments used for better utilization in buffaloes

Globally, biomasses from agricultural wastes are produced and consumed in large quantities. Another possible source of energy is organic agricultural waste, which can be utilized for livestock (Sommer et al., 2015). One notable source of possible raw materials for the manufacture of renewable fuels, chemicals, and energy is the residue from agro-industrial and forestry processes, which are by-products of important industrial and economic operations (Ajila et al., 2012). In order to increase crop yields, biomass from crop residues (CR) is utilized as fertilizer and as a feed resource. The demand for livestock products is expected to rise, leading to a phenomenon known as the "livestock revolution," which will in turn drive feed consumption and raise the use of CR for livestock feeding (Blummel et al., 2013). The utilization of agricultural biomass and industrial by-products would enhance ruminant production, which can be applied to various animal feeding strategies as notably shown by Wanapat et al. (2013a) and Wanapat, (2023) (Fig. 2).
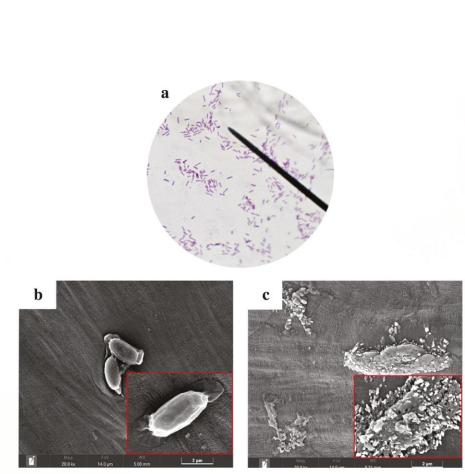
Figure 1. *Gram straining (a) and biodegradation of low-density polyethylene plastic by cellulolytic Pseudomonas aeruginosa isolated from buffalo rumen (b, c).*
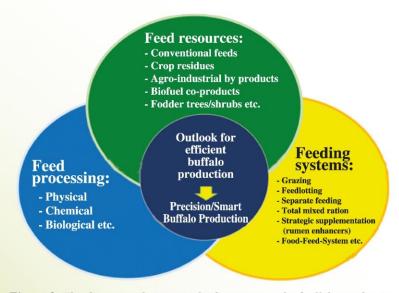
Figure 2. *The diagram of strategic feeding systems for buffalo production*
Source: Wanapat et al. (2013a); Wanapat, (2023).

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Figure 3. *The ingredients and preparation of urea and calcium hydroxide (lime) treated rice straw (2+2% U-lime straw)*
Source: Wanapat et al. (2023); Polyorach et al. (2018).

Mangosteen peel 450 g
Rambutan peel 300 g
Banana flower powder 150 g
Cassava starch 100 g

All feed ingredients were well mixed with water and processed through a pelleter to process the MARABAC pellet.

Sun dried 2-3 days

by using the pellet machine

Figure 4. *Preparation of phytonutrient pellet (MARABAC)*
Source: Toltakul et al. (2024); Wanapat et al. (2021).

By adopting this approach, low-cost livestock would then not to consume human-edible biomass, such as grains, but convert leftover streams into valuable feeds by improving nutritional quality and creating more efficient and sustainable feeding strategies for animals. Ruminants are important contributors to food security, providing both meat and milk. One of the major ruminants providing meat and milk to ensure food security is the buffalo (Wanapat et al., 2013b). Furthermore, buffaloes support both the farmers' way of the livelihood and livestock-crop production system. Buffaloes serve enormously for a variety of purposes in agriculture, including the production of meat, milk, draft power, savings as banks, transportation, and manure for crop cultivation. Because buffaloes are especially suited to harsh environments and can utilize excellent use of low-quality roughages, such as agricultural crop residues and by-products, their feed consumption is therefore more effective than that of cattle. When cattle and buffaloes are kept under similar conditions, their potential to produce meat utilizing locally available feed resources is consequently extraordinary (Borghese, 2010).
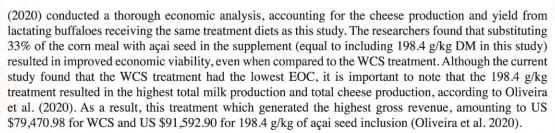
Rural communities find it more practical to use rice straw as fodder for buffalo calves rather than as a soil fertilizer or to make paper and wood products. One of the major agricultural residues in the rice-producing Asian nations of Bangladesh, China, India, Indonesia, Vietnam, and Thailand is rice straw. However, the limited and uneven nutritional content, high lignin and silica concentration, and low crude protein level of rice straw, all lead to poor voluntary intake and a slow rate of digestion (Khejornsart et al., 2021). In an effort to increase the nutritional value of rice straw through physical, chemical, and microbiological treatments, various large research has been conducted over the past few years. The use of rice straw as ruminant feed can be facilitated by a number of physical and chemical techniques (Khejornsar and Wanapat, 2011).

In addition, buffaloes will always be an essential ruminant contributing to many facets of the global population's participation in integrated farming systems. Through the existence of different microorganisms in the unique rumen ecosystem, their ability to utilize high fiber feeds, particularly those of agricultural crop-residues and by-products, has been considerably identified. This allows them to obtain the energy and protein they need for their productive activities (Wanapat et al., 2013b). Wanapat et al. (2023) and Polyorach et al. (2018) have shown to improve the quality of rice straw by using alkali (calcium hydroxide) and urea to improve the quality of rice straw to increase the utilization of CR for animal feeding (Fig. 3).

Recently, Wadhwa et al. (2023) reported that complete feed pellets made from paddy straw and their positive effect on buffalo calves' performance has been achieved. The utilization of complete feed pellets that are both isonitrogenous and isocaloric, and contained up to 35% paddy straw, can be accomplished successfully without compromising the health and performance of buffalo calves. Additionally, Wanapat et al. (2023) demonstrated that addition of phytonutrient fruit-peel pellets (MARABAC) and U-lime treatment to rice straw from the agricultural system has greatly enhanced the rumen fermentation of the ruminants. Therefore, dietary manipulation based on the pre-treatment of fibrous feeds and supplementation of phytonutrient pellets should be more intervened. Moreover, feeding interventions that utilize locally accessible resources should be widely implemented, with an emphasis on practical sustainability for all engaged stakeholders, from the farm level to the industrial platform. Ultimately, the scenario for buffalo production would be a system that is both environmentally friendly and economically feasible.

Economic enhancement in dairy and beef buffaloes by the use of agricultural biomass

Buffalo plays a critical role in the agricultural economies of numerous developing countries by providing milk, meat, and labor for pulling heavy loads (Warriach et al., 2015). According to FAO (2021), global dairy production has increased by approximately 51% over the past twenty years. This increase has consequently contributed to an increase in buffalo milk production in the tropical regions. Cunha et al. (2013) found a quadratic trend in DMP when dairy cows received higher amounts of palm cake, which is consistent with findings from research studies that investigated the use of other by-products from industries in milk production. Therefore, incorporating açaí palm seed at a rate of 396.8 g/kg could be advantageous in maximizing milk production in buffalo, according to the present findings. Oliveira et al.

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(2020) conducted a thorough economic analysis, accounting for the cheese production and yield from lactating buffaloes receiving the same treatment diets as this study. The researchers found that substituting 33% of the corn meal with açai seed in the supplement (equal to including 198.4 g/kg DM in this study) resulted in improved economic viability, even when compared to the WCS treatment. Although the current study found that the WCS treatment had the lowest EOC, it is important to note that the 198.4 g/kg treatment resulted in the highest total milk production and total cheese production, according to Oliveira et al. (2020). As a result, this treatment which generated the highest gross revenue, amounting to US $79,470.98 for WCS and US $91,592.90 for 198.4 g/kg of açai seed inclusion (Oliveira et al. 2020).
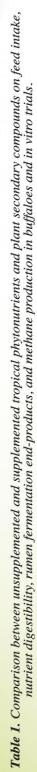
In the Asian developing countries, ruminant meat accounts for around 21.0% of total meat output. Buffalo meat, in particular, accounts for about 11.5% of the total ruminant meat and approximately 2.7% of all meat produced in the region (FAO, 2005). Wanapat and Rowlinson (2007) reported that swamp buffaloes were normally raised for draft and thereafter for meat production and now the process is moving forward for high-quality meat. Anjaneyulu et al. (2007) established that buffalo meat has been acknowledged as one of the most nutritious meats suitable for human consumption. The product possesses exceptional qualities, including reduced intramuscular fat, decreased cholesterol and calorie content, increased levels of vital amino acids, enhanced biological value, and elevated mineral content. Lapitan et al. (2008) reported that swamp buffalo, when receiving high levels of roughage rations, are better at utilizing the roughage than crossbred cattle when fed high roughage-based fattening rations such as Napier grass or Para grass supplemented with a limited amount of concentrate. Katiyar and Bisth (1988) showed that swamp buffalo have a greater ability to digest fibrous components, crude protein, and crude fiber in comparison with cattle. In addition, the calves fed TMR sugar beet pulp silage showed the highest daily weight growth of 856 g/d, outpacing the weight gain of calves fed citrus pulp silage (776 g/d) or green maize fodder (704 g/d). The calves consumed an equal amount of nutrients on average. Compared to other TMRs, the feed conversion ratio and digestibility of DM, NDF, and ADF were higher when using TMR sugar beet pulp silage. The economic benefit, measured as the ratio of output to input, was found to be 15.5%, 34.3%, and 37.4% higher for the fattening of buffalo calves when using TMR sugar beet pulp silage compared to citrus pulp silage, green maize fodder, and maize silage-based TMRs, respectively. Consequently, utilizing a combination of sugar beet pulp and ground corn cobs for ensiling is a straightforward and suitable approach for producing silage. Therefore, incorporating up to 50% of the dry matter in the TMR significantly influenced the economic outcomes of buffalo calf production (Anjum et al., 2022).

Mitigation of rumen production by phytonutrient pellet supplementation

Ruminants rely significantly on the end-products of rumen fermentation to sustain their meat and milk production. This fermentation process, known as the Embden-Meyerhof- Parnas pathway, is carried out by microorganisms in the rumen through anaerobic conditions. The rumen characteristics would be strongly influenced by the rumen fermentation end-products, which include volatile fatty acids, ammonia-nitrogen, microbial protein, and other substances (Russell and Rychlik, 2001; Wanapat et al., 2013a). A novel rumen enhancer called "Phytonutrient pellet" was developed using a combination of tropical plants and fruit peel that are rich in phytonutrients, such as phenolics, flavonoids, tannins, saponins, and antioxidant capacities (Wanapat et al., 2024b); these compounds can enhance rumen fermentation characteristics and reduce methane production and could be used as a feed supplement in ruminant diets, especially in buffaloes (Table 1). These findings agreed with Suriyapha et al. (2020), who demonstrated that bamboo grass pellets led to an increase in ruminal pH, improved propionate levels, and decreased methane production in swamp buffaloes; therefore, it has the potential to function as a dietary supplement that enhances rumen activity. Ampapon et al. (2019) stated that the inclusion of mangosteen peel and banana flower powder in the diet leads to remarkable enhancements in fiber digestibility, concentrations of bacterial populations (namely proteolytic and cellulolytic bacteria), and rumen volatile fatty acids. This is primarily achieved by an increased concentration of propionate and, subsequently, reduced production of methane in swamp buffaloes. The current study, Totakul et al. (2024) showed that the pellet contains phytonutrients obtained from mangosteen peel, rambutan peel, banana flower

Table 1. *Comparison between unsupplemented and supplemented tropical phytonutrients and plant secondary compounds on feed intake, nutrient digestibility, rumen fermentation end-products, and methane production in buffaloes and in vitro trials.*

Sources	Animals/trials	Level	DMI	DMD	pH	NH3N	TVFA	C2	C3	C4	CH4	PP	EMNS	References
Papaya peel	Indian native buffaloes	30% in concentrate	ns	ns	ns	+	+	nr	nr	nr	nr	nr	nr	Babu et al. (2006)
Lucerne fodder	Murrah buffaloes	30% in TMR	ns	nr	nr	ns	ns	-	+	+	ns	nr	nr	Malik et al. (2011)
Mangosteen peel+ Coconut oil	Swamp buffaloes	30 g/kg+50 g/kg	ns	ns	ns	+	+	-	+	+	ns	-	nr	Pilajun and Wanapat (2011)
Mangosteen peel powder+Centella powder	Swamp buffaloes	25 g/kg+25 g/kg	ns	ns	ns	+	ns	-	+	+	ns	-	ns	Norrapoke et al. (2014)
Mangosteen peel powder	Swamp buffaloes	100 g/h/d	ns	ns	ns	ns	ns	ns	+	+	ns	-	+	Wanapat et al. (2014)
Mangosteen peel powder+Banana flower powder	Swamp buffaloes	100 g/h/d	ns	ns	ns	+	+	-	+	+	-	-	nr	Ampapon et al. (2019)
Bamboo grass pellet	Swamp buffaloes	150 g/h/d	+	+	+	nr	ns	ns	+	+	ns	-	ns	Suriyapha et al. (2020)
Hydrolysable tannin	Nili Ravi buffaloes	30 g/h/d	ns	ns	+	ns	nr	nr	nr	nr	nr	nr	nr	Imran et al. (2021)
Bamboo grass pellet	In vitro	4% of total substrates	nr	+	ns	+	+	-	+	+	ns	-	nr	Viennasay et al. (2022)
Red Amaranth	In vitro	12% of total substrates	nr	+	ns	ns	+	-	+	+	-	-	-	Ampapon et al. (2022)
Fruit-peels pellet (mangosteen peel, rambutan peel, and banana flower) pellet+tung oil	In vitro	4% pellet +4% tung oil of total substrates	nr	+	nr	-	+	-	ns	ns	-	nr	nr	Prommachart et al. (2024)
Fruit-peels pellet (mangosteen peel, rambutan peel, and banana flower) pellet+lemongrass powder	In vitro	2% pellet+ 2% powder of total substrates	nr	+	ns	+	ns	ns	+	+	-	+	+	Toltakul et al (2024)

DMI, dry matter intake; DMD, dry matter digestibility; NH3-N, ammonia-nitrogen; TVFA, total volatile fatty acid; C2, acetate; C3, propionate; C4, butyrate; CH4, methane; PP, protozoal population; EMNS, efficiency of microbial nitrogen supply+, increase; -, decrease; ns, no significant; nr, not report. Modified from: Wanapat et al. (2024b).

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(MARABAC), and lemongrass, which significantly improved fermentation efficiency by increasing propionate concentration, nutrient degradability, while reducing methane production. Details of MARABAC pellet preparation is shown in Figure 4 (Wanapat et al., 2021; Totakul et al., 2024).

Conclusions

Current findings have revealed interesting results pertaining to the capability of buffaloes in relation to the rumen microbiomes and their degradability of high fibrous feeds as well as plastic wastes. Furthermore, development of feeding interventions based on the use of crop-residues and supplementation of phytonutrient pellets would significantly enhance the rumen fermentation efficiency while mitigating methane production by the buffaloes. Essentially, launching of feeding interventions based on local feed resources as on-farm is highly recommended to ensure food security and sustainability of the buffalo production system.

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Author's credit statement

- M. Wanapat: Supervision, Conceptualization, Computational framework, Validation, Data curation, Writing – original draft, Writing – review & editing.
- C. Suriyapha: Validation, Data curation, Writing – original draft, Writing – review & editing.
- G. Dagaew, M. Matra, S. Phupaboon, S. Pongsub, S. Sommai, U. Muslykhah, V. Chanthakhoun and V. T. Nguyen: Writing – original draft, provided critical feedback and manuscript editing.

All authors discussed the results and commented on the manuscript.

Declaration of interests

We declare that we have no financial or personal relationships with other people or organizations that can inappropriately influence our work, and there is no professional or other personal interest of any nature or kind in any product, service, and/or company that could be construed as influencing the content of this paper.

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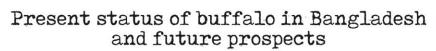
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11th ASIAN BUFFALO CONGRESS

COUNTRY PAPER

Present status of buffalo in Bangladesh and future prospects

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Introduction

Livestock is one of the most important sub-sectors of agriculture in Bangladesh which plays a fundamental role in promoting public health and national economy of the country. Buffaloes in Bangladesh are multipurpose indispensable large ruminant animals that play a key role as a main source of high quality animal protein (milk, meat) for human consumption, contribute to crop productivity through the provision of draught power and carriage, dung as fuel and natural fertilizer, employments and nourishment of poor households, and hides and skin as raw material for industry. Buffalo is next to the cattle in Bangladesh that has for a long time contributing to the smallholder farmer's vis-à-vis in national economy which are mainly managed in household subsistence of smallholder farmers and extensive *bathan* farming in saline coastal region in Bangladesh. In Bangladesh, buffalo has never been addressed and remained neglected species despite their important role in the national economy. In recent year's rapid growth of urbanization, poverty reduction, increase in middle class, and their increased income have changed their food preferences. These recent developments have major impacts on demand for animal origin products e.g. milk, meat, butter, cheese, ice-cream, baby foods, locally made traditional sweets which are merely dependent on milk.

Population

According to DLS (2023) the buffalo population in Bangladesh is 15.16 million. The buffalo population is very low in Bangladesh compared to the other SAARC countries especially India and Pakistan which might be due to indigenous buffaloes with lower production, seasonal breeding, lack of appropriate buffalo development plan and program, comparatively less acceptance of buffalo milk and meat to the people (Huque and Shjahan, 2016). The buffalo population, division wise distribution and top populated districts within the each division are summarized in Table 1. In Agricultural census 2019 (BBS, 2022) the buffalo population were reported to be 636926 and 90% of this buffaloes are found in the rural set-up while only 10% in the urban areas. Khulna division has the highest share of the countries buffalo (26% of the population) which is 9%, 11% and 13% more than the Chottogram, Rajshahi and Dhaka division, respectively. The Agricultural census 2019 showed deviation from the buffalo distribution map shown in Figure 1. Districts with highest number of buffaloes are shown to be in the Barishal, Chattogram, Sylhet and Rajshahi division.

Distribution and Available Breeds

In Bangladesh, different types and crosses of buffaloes are found throughout the country but there is no defined breed. The indigenous river type buffaloes are medium in size and vary from jet black to black in coat color. The indigenous swamp buffaloes are comparatively smaller in size with chevron and white color and crescent shaped horn. Medium sized animals with light black, chevron and white stoking are categorized as Bangladeshi type. The crossbred buffaloes are medium in size and characteristics vary based on the breed used in the crossbreeding. The major native buffaloes (*Bubalus bubalis*) are river type

Table1: *Division-wise distribution of buffaloes in Bangladesh and top populated districts in each division.*

Division and District	Number of buffaloes	
Bangladesh	636926	
Rural		572389
Urban		64537
Barishal Division	76951	
Rural		75366
Urban		1585
Patuakhali	37069	
Bhola	21470	
Barguna	7686	
Chattogram Division	106217	
Rural		98193
Urban		8024
Noakhali	26966	
Chattogram	26608	
Khagrachhari	10777	
Dhaka Division	85857	
Rural		40385
Urban		45472
Dhaka	44969	
Gazipur	16258	
Tangail	7872	
Khulna Division	166519	
Rural		164620
Urban		1899
Satkhira	92546	
Chuadanga	28251	
Kushtia	11878	
Mymenshingh Division	28254	
Rural		27596
Urban		658
Mymensingh	9129	
Jamalpur	8349	
Sherpur	7610	
Rajshahi Division	94691	
Rural		92014
Urban		2677
Pabna	21606	
Rajshahi	18021	
Naogaon	1366	
Rangpur Division	38630	
Rural		35552
Urban		3078
Rangpur	13572	
Kurigram	6058	
Dinajpur	5600	
Sylhet Division	39807	
Rural		38663
Urban		1144
Sylhet	18817	
Moulvibazar	10148	
Sunamgar	7173	

Source: Agriculture Census 2019, BBS (2022)

distributed throughout Bangladesh except some low productive swamp type in Eastern part. Some imported breeds including Murrah and Nili-Ravi are available now in few institutional/organizational farms. Border migration (mainly from India to Bangladesh and few from Myanmar to Bangladesh) of buffaloes is also evident. The immigrant buffaloes from India is mainly riverine type (Murrah, Surti, Jaffrabadi and Manipuri), whereas, it is swamp type from the Myanmar. These immigrant buffaloes and their crosses are available around Bangladesh-India border and Bangladesh-Myanmar border, respectively (Hamid et al., 2016; Hamid et al., 2016; Saadullah, 2012; Faruque and Amin, 1994; Faruque, 1990).
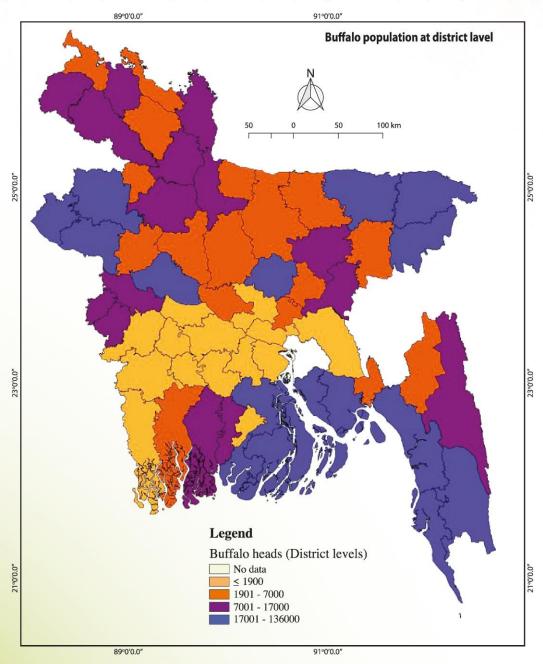
Buffalo population at district lavel

Legend

Buffalo heads (District levels)

- No data
- ≤ 1900
- 1901 - 7000
- 7001 - 17000
- 17001 - 136000

Figure 1: District wise distribution of buffalo in Bangladesh (LDDP, 2019).

Table 2: *Productive and reproductive performances (Range data) of buffaloes in different districts of Bangladesh.*

Variables	Bhola	Mymensingh	Dinajpur	Noakhali	Sylhet	Rajshahi
Body Weight (Kg)	182.0-320.0	340.0-420.0	356.0-381.0	305.5-506.7	-	-
Milk Yield (L/d)	1.0-5.0	1.3-7.3	3.0-9.2	1.1-9.06	2.85-4.15	3.4-3.7
4% FCM yield (kg/d)	1.5-5.9	1.6-9.0	4.0-10.4	-	-	-
Lactation length (d)	150.0-270.0	240.0-325.0	170.0-210.0	243.3-305.6	268.6-289.6	200.5-216.0
Lactation yield (L)	196.0-916.0	392.0-2156.0	567.0-2333.9	314.7-908.9	-	-
Dry Period (days)	30.0-214.1	-	97.2-172.7	-	-	-
Total Solids	12.8-19.6	15.4-17.0	16.4-18.2	-	16.3-17.8	-
Fat (%)	4.1-12.0	5.1-10.3	6.1-10.0	-	7.3-7.8	-
SNF	7.5-9.3	8.9-9.4	9.4-9.5	-	-	-
Protein (%)	3.0-4.4	3.1-4.1	3.7-4.7	-	3.9-4.2	-
Lactose (%)	3.6-4.8	4.3-5.8	4.3-5.0	-	-	-
Ash (%)	0.5-0.8	0.6-0.9	0.6-0.7	-	-	-
Age at puberty (month)	34.7-42.9	47.3-49.7	-	54.0-57.8	39.0-50.4	24.1-26.4
Age at first calving (month)	34.0-58.0	58.6-60.2	39.3-45.6	46.0-62.7	47.0-62.3	34.5-36.7

Variables	Bhola	Mymensingh	Dinajpur	Noakhali	Sylhet	Rajshahi
Number of service per conception	1.0-2.42	-	1.3-2.0	1.4-2.0	-	-
Conception rate (%)	-	39.7-41.4	-	38.7-41.5	-	-
Gestation length (day)	300.0-330.0	302.9-314.0	300.0-300.3	301.0-318.1	310.6-319.4	304.1-318.4
Post-partum heat period (days)	60.0-180.0	78.7-96.6	103.0-126.9	116.7-152.6	148.8-162.1	79.1-94.3
Calving Interval (days)	330.0-584.5	-	386.7-420.0	580.9-681.0	576.4-603.7	459.5-464.4
Calving season	-	August to January	-	August to January	-	-
Peak calving season	-	December	-	December	-	-

BW, Body weight; MY, Milk yield; d, day; FCM, Fat corrected milk. Values in the parenthesis represents the data range of the respective mean. FCM = 0.4M + 0.15F; M is the quantity of milk in Kg, F is fat content (Kg) of non-standard milk (Gaines, 1928).

Source: Rahman et al. (2019); Siddiquee et al. (2010); Momin et al., (2016); Kabir, & Sultana, (2017); Rahman et al. (2018); Famous et al. (2021); Rahman et al. (2019); Khaton et al. (2020); Habib et al. (2020).

Considering the agro-ecological zones of Bangladesh, buffaloes are mainly found in coastal area, marshy land, sugarcane belt, and hilly region. The dairy buffaloes are spread along the riverside villages of Rajshahi, Rangpur, Bogura, Jamalpur and Mymensingh districts. They are also distributed in coastal regions of Noakhali, Feni, Laxmipur, Satkhira, Bhola, Patuakhali and Borguna districts. Draught buffaloes are distributed in sugarcane belt and forest areas - in Jamalpur and Modhupur. The native buffaloes in the eastern part (Swamp type) found mainly in the marshy land of the greater Sylhet, Sunamganj and Chottogram. These buffaloes have chevrons and white stoking and grey and crescent horn. The indigenous buffaloes in the Rajshahi, Natore, Naogaon and Bogura are also known as indigenous Murrah type. They possess black coat color and curly horns. Some of them have hanging horns, brown coat color and spot in tail switch. These are the largest buffaloes in the country. The indigenous riverine type of buffalo is black, distributed in the central part of the country, alongside the river Brahammaputra and Jamuna belt that includes Rajshahi, Jessore, Rangpur, Bogura, Pabna, Jamalpur and Mymensingh district. Indigenous buffaloes in the southern part (coastal areas: Noakhali, Laxmipur, Bhola, Patuakhali, Borguna, Pirojpur, Bagerhat, Khulna, Satkhira and Chottogram) are wild type *Arni* or crossbred type. Among these crossbreds, river type and swamp type crosses are evident in the coastal areas (Sultana, 2018; Hamid et al., 2017 and Saadullah, 2012). The Department of Livestock Services (DLS) introduced some Nili-Ravi breed from the then West Pakistan in 1960 for breeding purpose in the coastal area of Southern part for cross-breeding. In 1964, the Department of Dairy Science of the then East Pakistan (presently Bangladesh) Agricultural University started to work on the development of dairy buffaloes in Bangladesh but unfortunately, immediate after its start the work has been discontinued due to some unavoidable reasons. In 1990, DLS again trade in 100 pregnant heifers and first lactating cows from Pakistan (Nili-Ravi breed) and were reared in Government Buffalo Breeding and Development Farm at Bagherhat district, which is in south-west part of Bangladesh. In addition, Murrah breed has been used for up-gradation of native buffaloes. In 2010, buffalo development project has started which includes cross-breeding of local buffaloes with Italian Mediterranean semen in limited areas using artificial insemination in 39 sub-districts of 13 districts. In 2018, Bangladesh Milk Producer's Co-operative Union Limited (BMPCUL; brand name – Milk Vita) imported 200 milking Murrah buffaloes with calf and are reared in Buffalo farms, Takerhat, Madaripur and in Buffalo farms, Raypur, Laxmipur (Samad, 2020). Moreover, few buffalo pockets are also available in Bangladesh e.g. Kanihari buffalo pocket which is located in Trishal Upazila of Mymensingh district. In Kanihari, the buffaloes are categorized in three types viz. Type-1, Type-2 and Type-3 locally known as *Gurjuti*, *Nepali* and *Deshi*, respectively. The *Gurjuti* type is Jet black in color with soft, smooth and scanty hair and the horn is short, tightly curled forming coil. The fawn or black buffaloes with sickle shaped horn (short to medium in size), rusty brown hair and black or white switch are the *Nepali* type. The *Deshi* type is black and has comparatively larger horn (Sohel and Amin, 2015).

Productive and Reproductive Performances

The productive and reproductive performances of buffaloes in different districts of Bangladesh are summarized in Table 2. Same for the different types and breeds are presented in Table 3 and 4, respectively. The river type buffalo appears heavier than the Swamp and crossbred buffalo. Among the district the heaviest buffalo was found in Noakhali with a live weight of 507 Kg and the thinner one with 182 Kg found in Bhola district. The birth weight of the male buffalo (28 Kg) is 2 Kg higher than the female buffalo (Momin et al., 2016). In another study, Chanda et al. (2021) reported 6 kg heavier buffalo calf in commercial farm (36 Kg) than the small scale farm leading to 3 months early weaning with 32 Kg less body weight at weaning.

On district perspective, the lowest milk yield was recorded in Bhola (1.0 L/d) and the maximum was found in Dinajpur (9.2 L/d) district. The river type buffaloes gave 2.5 times more milk than the Swamp type buffalo which was 1.94 times of the crossbred type. This is further varied based on the production system. Among the breeds, Murrah produce ≈4.0 L of milk per day followed by Nili-Ravi (≈3.5 L/d). Crossbred cow produce 1-2 L of milk less than the Murrah and Nili Ravi breed while the local produces

only 1.5 L of milk in a day. According to Chanda et al. (2021), the buffaloes in commercial farms produce 7 L milk per buffalo cow per day which is 1.9 times of the buffalo cow in small scale farm. In different locations, the lactation length also showed a greater variability with a minimum range value of 150 days and maximum was 325 days. Mymensingh and Noakhali district has record of lactation length more than 300 days and Sylhet was near to 300 days. The river type buffalo used mainly for dairy purpose could be the reason for this as evident from Table 3. The riverine breed data in Table 4 are in line with this. The lactation yield in Table 3 remains less than 1000 L but the maximum range value recorded was 2334 L in Dinajpur district. Data on dry period were reported only in a few districts and the minimum dry period recorded was 30 while the maximum was 214. The data on milk quality reflects the richness of buffalo milk in each of the tabulated districts.

Table 3: *Productive and reproductive performances of different types of buffaloes in different farming system of Bangladesh.*

Variables	Semi-intensive farming system			Extensive farming system		
	River type	Crossbred	Swamp type	River type	Crossbred	Swamp type
Male buffalo live weight (Kg)	457.8±10.8	362.5±8.9	359.9±8.6	442.8±21.7	396.7±11.4	352.6±10.5
Female buffalo live weight (Kg)	427.1±15.5	343.9±13.1	325.7±11.9	354.0±12.6	340.4±12.1	305.5±8.7
Milk yield (L/d)	3.1±0.2	1.6±0.1	1.25±0.1	2.5±0.1	1.85±0.1	1.1±0.1
Lactation length (d)	283.3±4.2	274.5±2.2	247.5±2.6	286.6±2.4	263.9±4.8	243.3±1.5
Lactation yield (L)	890.6±47.9	488.3±45.8	314.7±22.9	908.9±57.8	636.7±25.5	340.8±20.2
Age at first calving (month)	46.0±1.0	58.0±1.4	60.1±2.3	48.0±1.7	60.0±1.7	60.1±2.5
Number of service per conception	1.4±0.2	1.7±0.2	1.8±0.2	1.4±0.1	1.9±0.1	1.9±0.1
Gestation length (day)	301.0±0.6	305.3±0.8	309.5±0.9	302.4±0.7	307.7±0.5	309.2±0.6
Post-partum heat period (days)	129.8±9.1	145.2±4.4	152.6±8.3	116.7±5.8	139.5±5.8	145.9±4.2
Calving Interval (days)	580.9±37.0	673.8±57.2	666.4±59.7	762.5±50.6	647.4±30.4	681.0±24.4

Source: Momin et al. (2016)

Table 4: Productive and reproductive performances of different breeds of buffaloes in Bangladesh.

Characteristics	Local	Crossbred	Nili Ravi	Murrah
Milk yield (L/d)	1.5 ± 0.5	2.4 ± 0.9	3.4 ± 0.7	3.9 ± 0.9
Lactation length (d)	230.6 ± 34.8	246.5 ± 27.4	260.59 ± 22.5	250.9 ± 18.8
Sexual maturity (months)	34.4 ± 2.0	34.7 ± 1.8	34.1 ± 1.6	34.5 ± 2.0
Estrus cycle length (days)	21.9 ± 1.9	21.9 ± 1.5	21.2 ± 1.5	21.7 ± 1.8
Estrus duration (hours)	24.7 ± 3.0	23.9 ± 3.0	23.5 ± 1.6	23.1 ± 3.0
Insemination time after onset of estrus (hours)	11.8 ± 0.8	11.6 ± 0.9	11.6 ± 0.7	11.5 ± 1.0
First calving age (months)	46.1 ± 1.7	46.6 ± 1.6	47.1 ± 1.6	46.6 ± 1.5
Parity number	2.9 ± 1.2	2.5 ± 1.0	1.9 ± 0.6	1.9 ± 1.0
Number of service per conception	1.6 ± 0.8	1.8 ± 1.3	1.9 ± 0.7	1.4 ± 0.6
Gestation length (days)	312.1 ± 12.0	313.4 ± 5.0	314.5 ± 3.8	313.7 ± 4.7
Calving interval (months)	19.4 ± 2.4	19.4 ± 2.6	19.4 ± 1.7	18.3 ± 2.0
VWP (days)	66.9 ± 7.5	65.4 ± 7.2	68.1 ± 5.6	64.9 ± 8.5

VWP, voluntary waiting period. Source: Harun-Or-Rashid et al. (2019)
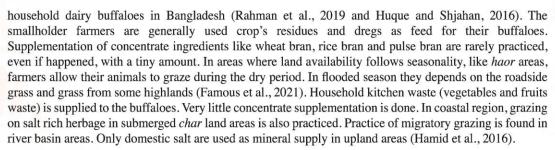
The buffaloes showed a wide range of variation in their age at puberty ranging from 34 – 54 months of age. Although in Bhola, first calving age was recorded as 34 months also in another study and the age at first calving recorded even at 62 months of age. Breed context gives more consistent view of age at first calving and age at puberty. Fertility in buffalo is always in discussion, especially the silent heat and therefore lessens the chance in conception. Nevertheless, pregnancy in single service is recorded in Bhola, however, number of service per conception may as high as 2.42. Local buffalo requires less service per conception than does the crossbred, Nili Ravi and Murrah buffalo. The riverine buffalo also requires less service than the Swamp type and crossbred. The conception rate of buffalo is low, ranging between 38 – 41%. The post-partum heat period was diversely different in different districts. Against the desirable 60 days of post-partum heat period, a maximum of 148 days was recorded. The variation was not so much in the river and swamp type buffaloes under different production system but all the values are 2 – 2.5 times of the desirable value. The gestation length showed the central tendency towards 300 days regardless of districts, types and breeds. However, the calving interval came up with great variability among the districts but more or less stable among the breeds and little variation among the types of buffalo in different production system. Chanda et al. (2021) found all the studied reproductive traits better in commercial farm compared to the small scale farm. It appears that the sampling technique, sample size, region of the study, management practices all need to be in line to obtain a better and robust data set.

Production and Management system

The buffalo production system is essentially founded on the landscape, shrubbery patterns and regular accessibility to the feed resources with minimum effort. Buffaloes are raised in Bangladesh all over the country with particular sharing in coastal districts, plain land, swampy land and bumpy/hilly areas. This highlighted distribution is mainly based on the availability of the feed resources and environment chosen by buffaloes. On the basis of all of these, major portion of buffaloes are raised under four production system viz. household subsistence (HF), semi-intensive farming (SIF), intensive farming (IF) and extensive farming system (EFS) in saline areas which covers about 23.00% of the total land areas of the country. The HF buffaloes are stall fed with 6 to 7 h grazing close to the backyard and/or public and/or fallow land with very little/scarce feed supply. The number of animals in this system ranged from 1 – 10 with most frequent herd size of 1 - 3. The HF system is practiced in areas neighboring to marshy land area, required hefty draft (inland forest, sugarcane cultivation and remote rural areas) and upper land to coastal areas (Huque and Shjahan, 2016). In Tangail, Jamalpur, Bogura, Sirajgonj, Kushtia, Pabna and Thakurgaon districts, buffaloes are largely reared in homestead farming. In SIF system, combination of household (in rice cultivation season) and free range system (when land is available for grazing) in practice. This is mostly common in upper part of coastal areas. The typical herd size is 4 to 15 buffaloes. In plain land and marshy land, buffaloes are raised under semi-intensive system; where buffaloes get access to a limited pasturing in common land and road sides. The IF system of buffalo farming is found in few institutional and organizational set up. The dairy farm of Bangladesh Agricultural University is pioneer in this context, used mainly for teaching, research and extension purposes. It is dedicated for dairy purpose along with their cattle herd mate. The DLS has the buffalo farm with a goal for buffalo improvement all over the country. The buffalo breeding and development farm of DLS is in Bagerhat and Dhaka district. The buffalo farm of Bangladesh Livestock Research Institute neighbors the DLS's buffalo breeding and development farm in Dhaka. The buffalo farms of BMPCUL are in Madaripur and Laxmipur District, Bangladesh. Buffalo Center of Lal Teer Livestock Limited in Mymensingh district, and buffalo stock of American Dairy Ltd in Gazipur district are also in the list. In IF system, the buffaloes are fed on cultivated grasses like Napier (*Pennisetum purpureum*), German (*Echinochloa polystachya*), Jumboo (*Sorghum bicolour*), Oat (*Arrhenatherum elatius*), rice straw (*Oryza sativa*) and formulated (mostly hand mixed but sometimes commercial) concentrate mixture. In the lower part of the coastal area, buffaloes are raised under EF system, known as *Bathan* system. The EFS in coastal areas includes offshore islands, mudflats, *chars* (accreted land), new accretions, and river basin areas, where vast grass land and seasonal forages are presented. These are used for grazing by the buffaloes. The usual herd size is about 51 to 200 animals, however, herd of 600 animals are also there. In *Bathan* system, the buffaloes are fed on natural grazing with almost no additional feed supply. The *Bathan* (extensive free range rearing) systems are mainly practiced in Bhola, Noakhali, Laxmipur and Patuakhali districts of Bangladesh. Approximately 91% of the farmers provide no housing/shelter to their buffaloes during night, 5% farmers kept them under the trees and only 3% provides a so called roof to them (Faruque et al., 2019 and Uddin et al., 2016). However, some development organizations are promoting the buffalo production in these areas through credit supply, improving the supply chain and training of the farmers and service providers. They are also investing to construct minimum housing facilities (known as *Killa*) to the buffaloes.

Farmers usually follow the old-fashioned feeding practices and it is completely based on their own farm produces or at least on the resources/supplies that does not incurs any additional cost with very minimum (or no) labor involvement. The primary feed for buffalo is the rice straw (and also other kind of straws like wheat, legumes etc.), maize stover, local green grass like *dol* (*Dichanthium annulatum*), *durba* (*Cynodon dactylon*), *halancha* (*Enhydra fluctuans*), sesbania/*dhaincha* (*Sesbania rostrata*), water hyacinth (*Eichhornia crassipes*), road side grass, rice field grazing (after rice harvesting), reeds in the fallow crop lands after harvesting, elephant grass, sugarcane leaves etc. Farmers in coastal (e.g. Bhola, Noakhali etc.) and river basin (Mymensingh, Jamalpur etc.) area used more diversified roughages for feeding their buffaloes than that of the farmers in drought area (Dinajpur, Thakurgaon etc.). The green roughage fed either fresh as pasture or in a cut-and-carry system. Sometimes rice bran, wheat bran, pulse bran, boiled broken rice, crushed maize, oil cakes, mineral and vitamin supplement are offered to intensive and

household dairy buffaloes in Bangladesh (Rahman et al., 2019 and Huque and Shjahan, 2016). The smallholder farmers are generally used crop's residues and dregs as feed for their buffaloes. Supplementation of concentrate ingredients like wheat bran, rice bran and pulse bran are rarely practiced, even if happened, with a tiny amount. In areas where land availability follows seasonality, like *haor* areas, farmers allow their animals to graze during the dry period. In flooded season they depends on the roadside grass and grass from some highlands (Famous et al., 2021). Household kitchen waste (vegetables and fruits waste) is supplied to the buffaloes. Very little concentrate supplementation is done. In coastal region, grazing on salt rich herbage in submerged *char* land areas is also practiced. Practice of migratory grazing is found in river basin areas. Only domestic salt are used as mineral supply in upland areas (Hamid et al., 2016).

Buffaloes showed heat mainly in winter and difficult to detect as the buffaloes showed silent heat. Natural mating is the common practice with very few artificial insemination and farmers confirms the pregnancy by non-return to estrus. The organizational farm like Lal Teer Buffalo center used the synchronization and artificial insemination and recorded impressive conception rate of about 60%. The Bangladesh Livestock Research Institute does the same but not as a regular farm practice rather for research. The silent heat of the buffalo also makes the timely insemination difficult which is important for pregnancy. The farmers usually don't have specialized breeding bull, and the buffalo in heat got bred by the herd mate or adult male from other herd during the grazing time. The DLS and Bangladesh Livestock Research Institute took initiatives to improve the buffaloes in Bangladesh through couple of development projects. The DLS is primarily focused on developing service provider who can also do the artificial insemination and makes the Murrah semen available to the farmers. Bangladesh Livestock Research Institute using biotechnological tools like embryo transfer along with the dissemination of Murrah semen for AI.

Diseases have lesser effects on the buffalo and its productivity compared to that of the cattle. Clinically the common buffalo diseases are mostly alike to cattle, however, with a very few exception, buffaloes are less susceptible to these diseases than the cattle. This disease resistance characteristics of the buffalo helps them to survive in hot humid areas. However, buffalo calves are very vulnerable to diseases than the adults. Calf pneumonia and diarrhea (due to management practices), environment, nutrition and physiological variations, and various infectious and parasitic agents are the utmost reasons of buffalo calf mortality (Deb et al., 2016). Buffaloes are comparatively less affected with ticks but highly susceptible to specific lice (*Haematopinus tuberculatus*; Mamun et al., 2010) Buffaloes are more vulnerable to Haemorrhagic septicemia than cattle. Brucellosis, tuberculosis, leptospirosis, bovine virus diarrhea, fascioliasis, FMD and protozoan infection have been reported to have economic impact to water buffaloes, whereas, leptospirosis, brucellosis, bovine tuberculosis and schistosomiasis have been reported to be associated with economic importance in buffalo industry but also has effects on public health. Samad (2020) pointed out from the inland reports that the overall prevalence of clinical and sub-clinical mastitis in Bangladesh is 5.06% and 30.09%, respectively. On animal perspective, the prevalence of sub-clinical mastitis ranged from 25 – 70% which is 23 – 32% among the different quarters of the udder. The maximum incidence of sub-clinical mastitis was noted at 9 to 12 years of age (23.33%), 4th parity (16.67%) and late lactation (30.0%). The average daily milk yield was trivially declined in sub-clinical mastitis affected buffaloes (4.5 L) than the buffaloes without sub-clinical mastitis (4.8 L; Kisku and Samad 2013). Colostrum feeding to calves, regular vaccination and deworming, hygienic condition in the production and management system, keeping the buffaloes mal-nourished and buffaloes wallowing habit are the major challenges to keep them healthy.

Marketing of the Buffalo Products

Salable produces from the buffalo farm are the live animals for meat purposes and milk for either direct consumption or for processing into different dairy products. Buffen, the buffalo meat is highly appreciated in some particular districts e.g. Jamalpur, Rangpur, Chattogram, Cox's Bazar, Comilla, Pabna, etc. However, nowadays, growing awareness for health quality of buffen draw the attention of the consumer and the meat sellers are also slaughtering the animals with optimum age and farmer raising the animals especially for meat purpose. All these are playing key role in developing buffen market in Bangladesh.

With regards to milk and milk products, the scenario is more or less similar to the case of buffen market. However, fermented raw buffalo milk curd of Bhola and Noakhali is very popular and mozzarella cheese to a lesser extend draw the nationwide attention of the consumers. Buffalo milk got premium payment in Mymensingh, Bhola, Noakhali, Natore and Pabna districts. This is because of their high fat and chhana (acid curd of milk) yield during the processing.

Like other agricultural produce in Bangladesh, the market linkage for buffalo products marketing is also very poor. There are other market actors in between the producers and consumers. This leads to compromised profit margin to the producers and higher product price to the consumers.

Constraints of buffalo production in Bangladesh

- Lack of high producing (milk, meat) buffalo breed.
- Lack of breeding infrastructure.
- Lack of genetic improvement programme.
- Poor reproductive performances.
- Unavailability of proven bulls.
- Lack of long-term breed development policy and research programme.
- Scarcity of quality feeds, fodder and pasture land.
- Lack of knowledge about the quality of buffalo milk and meat.
- Lack of public awareness about buffalo husbandry.
- Lack of record keeping.
- Lack of coordination within research and government organizations, universities, NGOs and beneficiaries.
- High mortality.
- Lack of attention.
- Poor management of calves.
- Lack of capital investment.
- Poor health management.
- Lack of Government policy.
- Public discrimination/misconception.

Recommendations of buffalo development in Bangladesh

- Import higher quality productive buffalo.
- Developing/strengthening the breeding infrastructure.
- Continuous up gradation/crossbreeding of native buffaloes.
- Awareness among the farmers about the selective breeding i.e. best to best mating.
- Selection within improved breeds for milk and meat.
- Improve reproductive technologies.
- Conservation of the swamp buffaloes.
- Breeding, feeding and disease prevention measures.
- Reproductive biotechnology should not be ignored.
- Public awareness for buffalo production by different media; radio, TV, newspaper etc. should be created.
- Quality fodder seed/germplasm production farms should be established.
- Increase the land for fodder production should be ensured.
- Development of manpower by technical training should be ascertained.
- National research and international collaboration should be strengthened.
- Buffalo milk and meat market and infrastructure should be developed.
- Private investment is to be explored and encouraged to invest in buffalo development.
- Development of infrastructure including marketing of milk and meat products in the country.
- Strengthening extension services.
- Training on buffalo production.
- Disease prevention and control strategies.
- Strategic policy from government.
- Provision of credit and incentives.
- Establish cooperative societies.
- Strengthening research.

Future Development plan

There are few components that may be considered in the development of buffalo in Bangladesh. Genotype being the most important and not alterable factor for determining the productivity of the buffaloes, therefore we need to address it first. For this, DLS is now working to have good structured record keeping system in the field. DLS, some NGOs and private enterprises are also focused in disseminating Murrah semen at field level through artificial insemination. Encouraging the farmers to cultivate fodders, offering the animals green grass/any good quality roughages, fed the animals on balanced ration, regular vaccination and deworming are also in their priority list. Bangladesh needs to take the buffaloes in intensive or semi-intensive system from the extensive system. The supply chain and value chain also need to be developed. Farm hygiene and hygiene in the workflow need to be ensured.

Conclusion

It is assumed that Buffalo farming either small scale or commercial can be an alternative good source to earn more profit. Many unemployed youths, poor farmers as well as industrialists have been becoming interested in this beneficiary Buffalo farming. There is a need for technical and institutional intervention to alleviate the identified constraints in buffalo production in Bangladesh which requires dissemination of appropriate technologies to the farmers. To improve the present buffalo production potential through scientific crossbreeding program through AI with quality semen, proper heat detection, animals body condition score, availability of the semen, skillful AI technicians are the requirements. Ensuring the availability of feeds and fodder, improved management system, establishing the reliable milk and meat market, providing adequate training to buffalo farmers, credit and finance will definitely encourage the entrepreneurs in the buffalo farming. Consultancy service, feed conservation, adoption of improved forage and use of agro-industrial by products, better disease prevention strategy, adequate veterinary service, create awareness of the buffalo farmers and infrastructure will catalyze further the improvement of the production of buffaloes in Bangladesh.

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Current status of buffalo production in Cambodia

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Abstract

Livestock production is one of the main agricultural activities which are defined as a diversified rural farming system. The animal production system is divided into two systems; smallholder and commercial farm. Smallholder operations has been and still is the predominant system for the last 5 years despite smallholder farms being on a significant decline and commercial production system being on a steady rise. Buffalo, specifically, is a highly valued agricultural animal for smallholders, but the production of this species has unfortunately declined in recent decades due to rising farm mechanization. While swamp buffalo still plays a role in farmland cultivation, this species' purposes has shifted from draft power to meat, and hide production. Rice straw and natural grass are the main feed for cattle/buffalo, and the majority of cattle/buffalos receive natural breeding services, but AI for cattle is being widely promoted and supported by the General Directorate of Animal Health and Production (GDAHP). Low nutrient intake, low productivity breed, and infectious disease occurrence are the main constraints leading the producers to lose their profit from the business. However, the incomes earned from animal production include direct income, indirect income and other income through animal activities and its products have largely contributed. Direct income in this report refers to the income collected by the state as tax payment. Taxes include: animal tax, sanitary inspection tax (hygiene/health inspection tax) and meat inspection tax collected at slaughterhouses. Indirect income refers to the income obtained from sale of animals and its products received by the farmers or owners of animal. As for other income through animal activities and animal products, it refers to the use of animals for draft, for plowing and harrowing, transporting, and providing of a hundred thousand metric tons of animal manure each year which in this report was not calculated or transformed into monetary figures but has been included as the other income earned from animal activities and their products. Income earned from animal production and its products such as hide, etc has not been estimated in this report.

Keywords: Buffalo production, smallholder farm, commercial farm, buffalo breed.

I. Introduction

Cambodia is largely known as an agricultural economy where agriculture contributes about 22.8% to the national GDP, rice production is the main share. Among sub-sectors, livestock shared 11.4% (MAFF, 2021), and most livestock was raised; chickens, duck, pigs, cattle and buffalos. It's around 70% are smallholder farms raising of native genetic resource breeds. The native breed roles crucially for generating household income, cheap source of protein for the poor, high demand for local consumers, well-adapted to the harsh environment at the rural condition also they represent rural ritual culture. Yet the native breed is low productivity, high mortality rate, random mating in the village and farm level are common. Smallholder farm livestock has been accepted as important issue and added to government strategic plan of Rectangular Strategy Phase-III, Pilla-2, and Improve livestock production and aquaculture, activity 5 of Agricultural Development Policy 2030, aimed at promoting smallholder farm to commercial farm which is high productivity, better profit, both quality and quantity to supply locally and importation. Many attempts to increase to production have not been successful, and the Innovation Platform for breeding improve has never been introduced. Cambodian native breeds are potentially a major source of diversity and, considering the absence of allelic diversity amongst commercial chickens owing to bottlenecking early in the development of the lines. Therefore, the immediate project to characterize, inventory, monitor, conserve and develop the local breeds are required to establish a
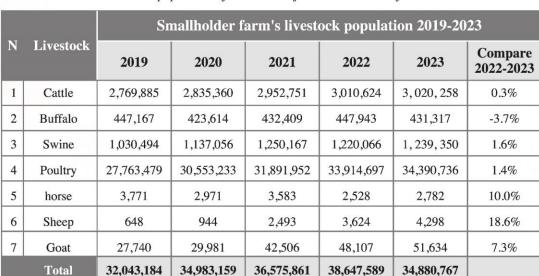
sustainable breeding program for improving the productivity of locally adapted breed to enhance the livelihood of smallholder farmers in Cambodia, and food security. Buffalo production provides many benefits, such as providing meat and milk which are important source of protein for human growth, as a source of traction, providing manure as a natural fertilizer that contributes to soil quality improvement, creating jobs as a source of income, and as a national identity and culture. The number of smallholders who have raised the livestock and the average number of livestock in family farms are as follows; 89.9% keep in range of 5-23 chickens, 66.9% keep in a range of 1-5 cattle, 46.1% keep in range of 1-5 pigs, and 15% keep 1-3 in a range of buffalo CelAgrid (2013). Cattle are the second most important animals in smallholder farms. Beef cattle farming is mostly smallholder production, with almost 70% raising domestic cattle and other farmers preferring to breed hybrids and imported breeds in small quantities, especially in lowland areas that are rich in fodder, enough water year-round, and good weather, where is favorable for cattle/buffalo husbandry. According to the 2023 Annual Report on Animal Production and Animal Health of the General Directorate of Animal Health and Production, cattle/buffalo production throughout the country is developing significantly with the increasing trend of a commercial farm. However, despite such rapid growth, the number of animals is still low compared to the number of smallholder cattle raised at about 3.5 million. The livestock population of both smallholder and commercial farms in Cambodia is shown in Table 1 and Table 2.

II. Animal production systems

The Kingdom of Cambodia is not much developed at cattle and buffalo raising even though these animals are extremely important and 80% of the population live in rural areas raise animals for agriculture activity. Two production systems for all species of domesticated animals have been recorded in Cambodia: subsistence and commercial production system. Subsistence production is involved by majority farmers who raise the animal for self- consumption and sometimes for saving income. Usually, such production is carried out extensively and feeds based on whatever available: 1/ natural grass along the road sides, in the rice field before planting rice or after harvest or natural grass and plant leaves in Chamkar (an area where fruit trees, crops, plants or vegetables are planted) as well as surrounding household area (for cattle and buffalo); 2/ free scavenging (poultry) and waste from kitchen plus rice, rice bran and broken rice at home for pig. In contrast to subsistence production system, commercial production system is a business type of production, where technology is used to benefit from the production. This is an intensive production with consideration on selection of breed, feed formulation and feeding technique. Smallholder refers to the farm size less than 20 to 100 heads of Cattle/Buffalo, pig less than 50 to 100 head, chicken less than 100 to 200 head per farm respectively. commercial refers to farm size more than 20-100 and 50-100 heads of pig and chicken more than 100 to 200 head per farm respectively.

II.1. Smallholder's livestock production

Cattle and buffalo in this type of production system has not made much progress both in quantity, productivity and production technology. Total about 35 million head of livestock in 2023, including 3.02 million cattle, 431.32 thousand buffaloes, 1.24 million swine, 34.39 million poultry, horses. 2,782, sheep 4,292, and 51,634 goats. Compared to 2022, the total household livestock growth rate increased by cattle increased by 0.3%, buffalo decreased by -3.7%, swine increased 1.6%, poultry increased by 1.4%, horses increased by 10%, sheep increased by 18.6% and goats Increased by 7.3%, Cattle and buffalo are almost belonged to the people in rural areas who do paddy cultivation. The main purpose of cattle and buffalo raising is to use these animals as draft animals for plowing and harrowing, pulling carts, transportation as well as to provide fertilizers to paddy fields and crops. On Average, each household has approximately 1.33 cattle or 1.62 cattle and buffaloes, cow or a female reproductive buffalo (many cows or female buffaloes in case of scarcity) for calves to replace old cattle or buffalo. Cattle or buffalo are sold for money only at times necessity or when the numbers increases beyond the needs or ability to raise or care for the animals.

Table 1: *Livestock population of smallholder farms in Cambodia from 2019-2023.*

| N | Livestock | Smallholder farm's livestock population 2019-2023 | | | | | |
		2019	2020	2021	2022	2023	Compare 2022-2023
1	Cattle	2,769,885	2,835,360	2,952,751	3,010,624	3, 020, 258	0.3%
2	Buffalo	447,167	423,614	432,409	447,943	431,317	-3.7%
3	Swine	1,030,494	1,137,056	1,250,167	1,220,066	1, 239, 350	1.6%
4	Poultry	27,763,479	30,553,233	31,891,952	33,914,697	34,390,736	1.4%
5	horse	3,771	2,971	3,583	2,528	2,782	10.0%
6	Sheep	648	944	2,493	3,624	4,298	18.6%
7	Goat	27,740	29,981	42,506	48,107	51,634	7.3%
	Total	**32,043,184**	**34,983,159**	**36,575,861**	**38,647,589**	**34,880,767**	

Source: GDAHP, 2023

There are three types of cattle breed in the subsistence production system: Khmer cattle (Kor Khmer), Haryana and Brahman. Haryana and Brahman breeds are found in Kandal province and other parts of provinces surrounding Mekong river. Khmer cattle are found throughout the country in exception of Kandal. Two buffalo breeds raised by farmers are: mountain buffalo and plain buffalo (Krabai Kdam). Mountain buffalo is raised along the water's edge and jungle edge areas with mild cold climate such as in provinces of Rotanak Kiri, Preah Vihear, Kampot, Krong Preah Sihanouk, Kaoh Kong, Kracheh, Steung Traeng. Plain buffalo (Krabai Kdam) is seen in the province of Prey Veaeng, Svay Rieng, Takaev, Kampong Cham, Kampong Thum, Siem Reab, Bat Dambang, Poursat and Kampong Chhnang. The subsistence production system in pig production is extensive which consists of one-two pigs per family of the majority of Cambodian people in the rural area. The purpose of subsistence system (extensive technique), comprising of one-two heads is saving money, feeding kitchen's waste, rice bran and broken rice. Majority of people in the rural areas is using such the production technology. Pig in this production system represents more than half of the pig population in the country. Most of breeds kept by farmers are local breeds, which are more resistance to diseases, well adaptation to local climate and poor nutrition. According to extensive raising technique, health care and feeding, its growth rate are slow and carcass with thick fat. Pig breeds kept in the subsistence production system are not documented in this report.

II.2. Commercial's production system

Commercial livestock in 2023 total 27,34 million head including 34,738 cattle, 100 buffaloes, 2,344 653 million swine, 24,960, 647 million poultry and 40 horses. 2,250 sheep, 1,370 goats. Compared to 2022, the total household livestock growth rate increased by 3.3%, in which cattle increased by 118,7%, buffalo increased by100%, swine increased 6%, poultry increased by 3%, horses increased by 207,7%, sheep increased by 18.4% and goats Increased by 29,9%, There are few private cattle/buffalo farms, consist of from 100 to 6000 heads of cattle in each farm in the country. There have not been any big investments made for large scale buffalo production in Cambodia up to this date. Commercial production system, especially large scale-commercial pig production (semi/industrial type) has been introduced in the country since 1997, which lifted a change and development in this sector in addition to the subsistence production belonged to majority of the people living the rural area. Commercial production system is a type of business which has two objectives: 1) raising for sale of piglets for

breed and; 2) raising for meat. Before 1997, most of the pig breeds were imported into Cambodia from Thailand, Vietnam and small numbers imported from other countries such as Taiwan. At present, pig breeds are still being imported from neighboring countries, more particularly by provinces close to the borders such as Banteay Mean Chey, Bat Dambang but at the same times, there are farms that produce pig breeds in Cambodia which are supplying and distributing improved varieties for local needs. Most of pig breeds kept in large-scale production are Landrace, Duroc and Yorkshire. Poultry farming have also undergone interesting changes. In addition to the chicken raising traditionally (chicken are freely scavenging), there is also poultry farms where each farm consists of thousand and more than thousand heads supply the needs for meat and eggs. This kind of farm has developed from raising chickens in hundreds to raising chickens in thousands, however Cambodian people still prefer to eat meat of chicken of local breeds.

Table 2: Livestock population of commercial farms in Cambodia from 2019-2023.

N	Livestock	Commercial farm's livestock population 2019-2023					
		2019	**2020**	**2021**	**2022**	**2023**	**Compare 2022-2023**
1	Cattle	9,877	13,216	14,647	15,884	34,738	118.7%
2	Buffalo	218	211	150	-	100	100%
3	Swine	1,155,431	1,379,623	1,768,630	2,210,996	2,344,653	6.0%
4	Poultry	12,631,974	17,508,936	21,530,752	24,240,290	24,960,647	3.0%
5	Equine	30	-	-	13	40	207.7%
6	Sheep	0	781	1,800	1,900	2,250	18.4%
7	Goat	0	300	1,055	1,055	1,370	29.9%
	Total	**13,797,530**	**18,903,067**	**23,317,034**	**26,470,138**	**27,343,798**	

Source: GDAHP, 2023

Table 3: Percentage of smallholder and commercial animal Production from 2019-2023.

Category Anmal proction	Percentage of animal production in last 5years (2029-2023)					Category Anmal proction
	2019	**2020**	**2021**	**2022**	**2023**	
Smallholder	70%	65%	61%	59.3%	58.8%	-0.5
Commercial	30%	35%	39%	40.7%	41.2%	0.5
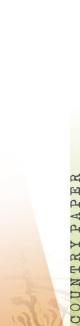
Source: GDAHP, 2023

III. Buffalo Breed

Type of Buffalo in Cambodia

Swamp buffaloes in Southeast Asia are raised by smallholder farmers because of their powerful draft capacity (OECD, 2017). This animal is utilized mostly for land cultivation; though it also provides milk, meat, hide, and horn, which are additional income sources to the farmers. However, due to increased farm mechanization, swamp buffalo have declined in value and its production has decreased by 4.92% for the last two decades (FAOSTAT, 2018). While swamp buffalo still holds a significant role in farmland cultivation, the purpose of this animal has shifted from draft power to meat and milk production.

Buffalo in Cambodia are called by different names depending on locations but it looks similar to the wild

buffalo (*Bubalus Bubalis*) and it maybe has common ancestry with the wild buffalo. They noticed that the buffaloes have existed for a very long time and there is no record of to import from overseas.

Khmer name : Krobai Srok
Scientific name: *Bubalus Bubalis*
Group : Swamp Buffalo

III. 1.Mountain buffalo

This kind of buffalo is raised along the water's edge and jungle edge areas with favorable climates such as in provinces of Rotanak Kiri, Preah Vihear, Kampot, Krong Preah Sihanouk, Kaoh Kong, Kratie, Steung Traeng. It has a big body and dark brown color.

Mountain buffalo have an average size:
Adult live weight 500-650 kg (male)
Adult live weight 350-450 kg (female)
Height 137-150 cm.
Length 125-160 cm

This mountain buffalo has suitable for mountainous area can pull the traditional cart with the highest weight, varying from 700-1,000 kg.

III. 2. Plain buffalo or Krabai Kdam

Its look does not differ from mountain buffalo. Its body size is smaller and height is slightly short. this buffalo is used as a traditional draft power. Farmers raising buffaloes in the rice production areas where is hot climates. Most of the buffaloes are smaller and taller than the mountain buffaloes, so much so that some farmers call them crab buffalo. Field buffalo are smaller and shorter than mountain buffalo. Most of the buffalo found at the forest are large, similar to mountain buffaloes, Plain buffalo is tolerances with tropical climate it is most capable animal in plowing the rice field, it can plow 0.05-0.11 ha/h.

Plain buffalo buffalo have an average size:
Adult live weight 400-550 kg (male)
Adult live weight 300-400 kg (female)
height 120-137 cm
body length 212-157cm

III .3. Krabai Sampov buffalo

This buffalo breed is not very abundant now day. This variety has a large shape, large bones, large legs, wide horns and rounded horns. This variety is mostly found in the Tonle Sap area, especially in Kandal province.

Krabai Sampov have an average size:
Adult live weight 700-750 kg (male)
Adult live weight 450-500 kg (female)
height 135 to 145 cm
body length 212-157cm

III. 4. Kon Taing buffalo

This buffalo is smaller than the sampov buffalo, thick, large bones, short body, deep chest, moderately large legs and large flat horns. This variety is mostly found in some provinces such as Kampot, Takeo and Kampong Thom.

Kon Taing buffalo have an average size:
Adult live weight 500-760 kg (male)
Adult live weight 350-450 kg (female)
height 120 to 130 cm
body length 212-157cm

Table 4: *Livestock population of commercial farms in Cambodia from 2019-2023.*

N		Buffalo stsstitic from 2013-2023										
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
1	Cattle	3,376,805	3,059,927	2,916,709	2,920,314	2,971,722	2,928,534	2,779,762	2,835,360	2,877,594	3,010,624	3,054,996
2	Buffalo	656,975	541,859	506,228	523,514	508,656	500,995	447,167	423,614	425,954	431,317	431,417
3	Swine	2,208,611	2,735,717	2,774,364	2,870,624	3,074,283	2,747,885	2,185,924	2,516,679	3,018,797	341,062	3,584,003
4	Poultry	23,348,430	31,583,657	34,519,073	35,733,761	36,244,939	38,166,751	40,395,453	48,062,169	51,035,192	58,154,987	59,351,383
5	Horse	12,531	10,897	7,689	5,674	5,137	4,296	3,801	2,971	3,583	2,541	2,822
6	Sheep	-		409	467	461	459	648	1,725	4,293	5,524	6,548
7	Goat	-	-	28,868	28,977	28,907	26,447	27,740	30,281	43,561	49,162	53,004

IV. Income from Animal production

The incomes earned from animal production include direct income, indirect income and other income through animal activities and its products. Direct income in this report refers to the income collected by the state as tax payment. Taxes include: animal tax, sanitary inspection tax (hygiene/health inspection tax) and meat inspection tax collected at the slaughterhouse. Indirect income refers to the income obtained from sale of animals and its products received by the farmers or owners of animal. As for other income through animal activities and animal products, it refers to the use of animals for draft, for plowing and harrowing, transporting, and providing of a hundred thousand metric tons of animal manure each year which in this report was not calculated or transformed into monetary figures but has been included as the other income earned from animal activity and their products. Income earned from animal production and its products such as hide, etc has not been estimated in this report.

Table 5: *Financial analysis on cattle/buffalo fattening 1head/90days.*

No.	Description	Unit	Amount	Price/unit ($)	Total price ($)
a. Expenses for cattle /buffalo fattening (1head/90days)					
1	Fattening cattle/buffalo	head	1	400	400
2	Rice bran	kg	50	0.25	13
3	Green grass	kg	300	0.125	38
4	Rice straw	pick up	1	20	20
5	Medicine	set	4	5	20
6	Vaccine (FMD, HS, BF,LSD)	dose	4	5	20
7	Labor	Person	1	50	50
8	Electricity/fuel/water	1 month	12	3	36
9	Grass seed	kg	0.5	31	16
10	Insemination service	service	1	50	50
Total expenses					**662**
b. Income					
Selling cattle/buffalo		head	1	780	780
c. Net Income					
1	Income				780
2	Total expenses				662
3	Net income				**119**

Source: Department of Animal Production of GDAHP (personal communication with fattening farmer)
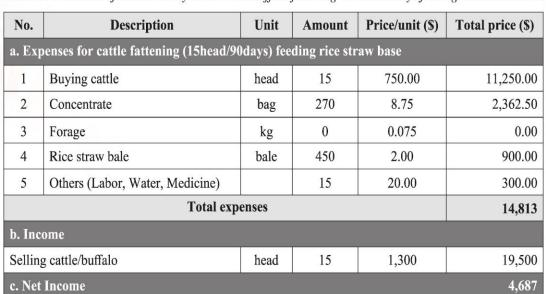
Table 6: *Production financial analysis on cattle/buffalo fattening 15head/90days feeding rice straw base.*

No.	Description	Unit	Amount	Price/unit ($)	Total price ($)
a. Expenses for cattle fattening (15head/90days) feeding rice straw base					
1	Buying cattle	head	15	750.00	11,250.00
2	Concentrate	bag	270	8.75	2,362.50
3	Forage	kg	0	0.075	0.00
4	Rice straw bale	bale	450	2.00	900.00
5	Others (Labor, Water, Medicine)		15	20.00	300.00
Total expenses					**14,813**
b. Income					
Selling cattle/buffalo		head	15	1,300	19,500
c. Net Income					**4,687**

V. Buffalo feeding and nutrition

The main feed resources of smallholder buffalo production in rural Cambodia is rice straw, pasture grass, cut-and-carry grass, rice bran, banana stem, maize Stover, sugarcane tops, cassava leave and root, soybean vine, forage crops, sugar palm seed (Pok et al., 2015). buffalo feed mainly consist of rice straw and natural grasses (cut-and-carry or free grazing), on average a head eat about 200 kg rice straw every month or about 136 kg of fresh grass per month. During scarcity of feed especially dry season and flooding season, farmer provide only rice straw to their animal. The feeding for buffalo is dependent on the seasonal variation, so the herd management is mostly carried out base on the seasons (Darith et al., 2016). In both season, rice straw was the main feed for cattle/buffalo. According to buffalo feed structure, May June, September, October, the feed value of rice straw and fresh grass get the real feed month. Cambodia buffalo smallholder production mostly experience a year-round feed deficiency as the variable climate and the dominant land for rice production. Rice straw is the main crop-residue which farmers usually store for use as ruminant feed in tropical areas, especially in Asia. However, rice straw is low in nutritive value with low level of protein (2–5%DM), high fiber and lignin content (NDF > 50%), low DM digestibility (< 65%) thus resulting in low voluntary feed intake (1.5–2.0%) whoever urea-treated rice straw could increase overall intake, digestibility, thus resulted in enhancing the performance of ruminants as compared to untreated rice straw(Wanapat et al., 1985).

VI. Animal and Meat Demands

In 2023, the consumption of meat in Cambodia per person per year is about 18.5 kg of meat, including 5.15 kg of beef and buffalo, 9.35 kg of pork. 3.95 kg of poultry and 0.05 kg of lamb and goat.

In the last five years, the demand for meat has increased significantly, from 290 thousand tons in 2019 to 327 thousand tons in 2023. In particular, in 2023, the total demand for meat is 327 thousand tons, including 91,000 tons of beef and buffalo, 165 thousand tons of pork, 70,000 tons of poultry and 1,000 tons of lamb, goat or other meat. Domestic animal production can supply about 320,000 tons of meat, equivalent to 98% of the total demand, including 90,000 tons of beef and buffalo (816 thousand), 165 thousand tons of pork (3.31 million), poultry 65 thousand tons (54.27 thousand head). The scarcity of meat is imported from abroad to meet the additional demand for food and as a raw material for animal feed (dogs). In fact, in 2023, Cambodia imported a total of 9.25 thousand tons of meat and livestock, including
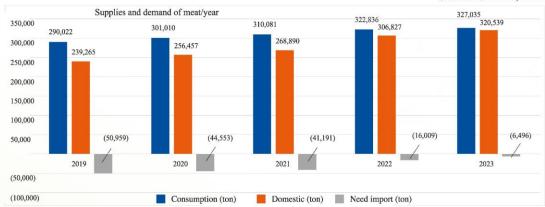
3,000 pigs, 336 goats, 400 sheep, 3.55 million live chickens, 170 thousand live ducks. Heads (4.49 thousand tons) and mixed meats include pork, sheep, chicken, duck, goose, orange, beef, meatballs, sausages, cheese and animal products (4.76 thousand tons).

Table 8: Demand and Supplies of meat.

N	Animal species	Demand		Supply			Insuffient		
		Meat (tone)	Number of animal	Meat (tone)	Number of animal	%	Meat (tone)	Number of animal	%
1	Cattle and Buffalo	91,040	828,000	89,787	816,000	98.6%	-1253	-11000	-0.14
2	Pig	165,285	3,306,000	165,405	3,308,000	100.1%	120	2000	0.1%
3	Poultry	69,826	58,189	65,127	54,272,000	93.3%	-4700	-3916000	-6.7%
4	Sheep and goat	884	88,000	221	32	25.0%	-663	-66000	-75.0%
	Total	**327,035**		**320,540**		**98.0%**	**-6496**		**-2.0%**

Source: GDAHP, 2023

VII. Exports of Animals and Animal Products
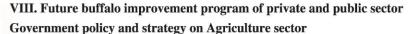
Cambodia is also able to export cattle, buffaloes, pigs, chickens, monkeys, animal products, animal feed and some milk to foreign countries. In the past 5 years, Cambodia has exported 115.37 thousand head of cattle and buffaloes, 15.25 thousand head of swine, 1.76 thousand head of pigs (breed), 102.58 thousand head of monkeys. 6.84 thousand tons of milk, 26.78 thousand tons of dog feed, 146.8 tons of fur, 27.16 thousand tons of cow and buffalo hide and 752 tons of gelatine.

Table 9. Export of Animal and animal production.

Category	Unit	2019	2020	2021	2022	Total
Cattle and Buffalo	Head	56 218	9 742	4 698	13 459	115 378
Pork	Head				8 450	15 250
Pig breed	Head	200	200	717		1763
Monkey	Head	16196	23 770	23 247	25 035	102 585
milk	Tons	3 984		381	2 478	6 843
Dog feed	Tons	1 011	2 276	4 881	7 666	26 781
Fur	Tons	8	2.8	12	105.7	146.8
Wet cattle and buffalo hide	Tons	1 440	1 554	104	200	3 298
dry cattle and buffalo hide	Tons			900	20 422	23 784
Dry Pig skin	Tons			46	47	93
Gelatine						752

Source: GDAHP, 2023

VIII. Future buffalo improvement program of private and public sector

Government policy and strategy on Agriculture sector

The Royal Government of Cambodia considers agriculture as one of the top priority sectors, including the sub-sectors of animal health and animal production. It has actively contributed to ensuring food security, promoting rural economic development, improving people's livelihoods, reducing poverty and sustaining extreme economic growth. To achieve the first phase of the Pentagon Strategy, the Royal Government has set out a number of policies:

1. 2023-2028 has set out nine policies related to the agricultural sector, the fourth point is directly related to the sub-sector of animal health and animal production. "Continue to support family and commercial animal husbandry, increase meat supply, improve animal health and public welfare, increase research capacity and animal disease diagnostic laboratories, strengthen partnerships with animal husbandry communities, and strengthen law enforcement." "Animal health and animal production."

2. 2022-2030, strategies for animal health and production sub-sectors focusing on "increasing productivity and value added in the animal production value chain, including:

* Promote the implementation of the Strategic Plan for Livestock Sub-Sector Development Plan 2016-2025 and make Update this plan for the next 10 years.

* Promote competitive animal production and environment (Good Animal Husbandry Pratices, improve animal breeding, technical quality, food safety, animal breeding)

* Promote animal health, animal welfare and public health (biosafety, reduce animal morbidity and mortality, produce vaccines, veterinary drugs, veterinary medicine, animal meat and animal kill products with ethics, animal disease diagnostic laboratory)

* Promote the dissemination of techniques and training, as well as strengthen law enforcement and promote animal health research and animal production.

* Promote partnerships with the private sector, livestock associations/communities, and strengthen international cooperation in the sub-sectors of animal health and animal production, facilitate private investment in animal husbandry, establish feed mills, produce vaccines.

* And livestock, as well as processing for export, continue to encourage rural family animal husbandry, which can be an additional source of income for smallholder farmers, as well as provide inputs that have a positive effect on animal husbandry.

* Continue to encourage rural family animal husbandry, which can be an additional source of income for smallholder farmers, as well as provide inputs that have a positive effect on animal husbandry.
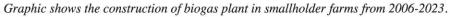
IX. Animal Waste Management

Animal waste contributes to greenhouse gas emissions, global warming and ozone depletion. More construction of biogas plants will help reduce the greenhouse gas emission. Moreover, an adult buffalo produces about six tons of manure a year. When their waste is properly managed through equipping families with biogas digesters, precious methane can be harvested and used to power stoves and lamps; thus, alleviating some financial burden for families (Annie Bergman October 3, 2019).

Eighty percent of Cambodian families in rural areas still use wood as the primary fuel source for cooking. When combined with a clean cookstove, a biodigester system creates a smoke-free cooking environment, producing benefits to respiratory health and safety, particularly for women and children.

According to the report of the National Biodigester Program as of June 17, 2021, if a farmer has a biodigester, he can save 2 tons of firewood or charcoal / year and contribute to reducing greenhouse gas $CO_2 = 3.2$ tons per biogas plant . If a farmer uses waste from a biogas plant, he save 1 million riel / year from not buying chemical fertilizers.

Graphic shows the construction of biogas plant in smallholder farms from 2006-2023.

The number of biogas plant construction from 2006 - 2023

In overall the benefits of biodigesters include:

Social benefits
- Avoided health hazards associated with unmanaged waste in farmyards;
- Reduced drudgery and time expenditure on wood collection and chopping;
- Provision of a renewable energy resource;
- Bright light from biogas lamps enables educational activities and household works in the evening;
- Increase in rate of enrolment of children in school because of the liberty from fuel collection.

Environmental benefits
- Reduced local environmental pollution through a better waste management system, and soil improvement by the use of bio-slurry;
- Reduced deforestation;
- Closing of the nutrient loops by nutrient recovery from waste;
- Increase in soil productivity due to added NPK and micro nutrients from bio-slurry;
- Reduction in greenhouse gas emissions to the atmosphere;
- Prevention in land-fertility degradation due the reduction of the use of chemical fertilizers.

Economic benefits
- Savings to national economy by providing renewable cooking and lighting fuel instead of imported fossil fuels;
- Reduced expenditure on cooking and lighting fuels;
- Savings to national economy by providing organic fertilizer instead of imported chemical fertilizers while achieving better crop yields;
- Employment opportunities for biogas construction and at Micro-Finance Institutions;
- Reduced pressure on the forests; the forest in Cambodia have a considerable potential for other uses than firewood and timber, i.e. non-timer forest products and tourism.

X. Conclusions

The buffalo raising within the Kingdom of Cambodia is not yet developed while most of animals belong to stallholder farmers. One of the negative results in animal productivity improvement is the lack of production technology, health, feed and feeding, breed selection and breeding, credit and market as the national services of production and animal health are still limited. In whatever way, the animal resources in Cambodia are playing a key role to participate in earning income and supplying food to the country. In order to maintain and protect the uses of existing animal resources effectively and sustainable towards the development, essentially it requires international assistance and cooperation:

* To continue close cooperation with bilateral or multilateral countries, international organizations to study and conduct researches on animal genetic resources in Cambodia more deeply and precisely (statistics, animal breeds and other animal species, which are not yet included in this report).
* To provide technical assistance and finance from bilateral or multilateral countries, international organization.
* To discuss with the countries in the region and international organizations to provide information and consultation concerning the protection of genetic resources and its development.

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ANNEX
Buffalo Breed in Cambodia

Mountain buffalo
Balong district, Ratanak Kiri province
Photographer: Mr. SIEK Darith August 2nd, 2010

Krabei Sro Ngae
Balong Russey Treb Park, Pheah Virear province
Photographer: Mr.Puthearo Bun, June 27, 2023

ANNEX
Buffalo Breed in Cambodia

Krabei Kon Taing
Balong Russey Treb Park, Pheah Virear province
Photographer: Mr. Puthearo Ben ,June 26, 2024
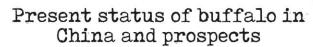
Krabei Sam Pov
Balong Russey Treb Park, Pheah Virear province
Photographer: Mr.Puthearo Bun, June 27, 2024

COUNTRY PAPER

Present status of buffalo in China and prospects

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Abstract

China has 30 buffalo breeds, mostly swamp buffalo. River buffalo excel in milk, while swamp buffalo serve draught. As mechanization advances, buffaloes shift to meat, dairy, or both. China's dairy buffalo industry grew rapidly, reaching 6 billion yuan in 2023, yet contributes only 1.54% to total animal husbandry, suggesting vast expansion potential. Four farming models exist, with elephant grass, corn stalks, etc. as common feeds. China has crossbred and genetically improved buffaloes since 1957, achieving good results, and is implementing a national genetic improvement plan. China's buffalo milk industry clusters in the south, especially Guangxi Province, with 22 manufacturers offering over 20 dairy products. Offline sales dominate at about 60%, while online sales take about 40%. Challenges include poor germplasm, feed scarcity, low milk yield, and brand/quality issues. Government, research institutions, and breeding enterprises must collaborate to enhance breeding, quality, and industry development.

Keywords: Buffalo milk, genetic improvement, buffalo nutrition, feeding models, marketing strategies.

1. Importance of buffalo in livestock sector, agricultural sector and national economy

China has a history of domesticating buffaloes in the Yangtze River Basin during the Neolithic Age (around 5000-7000 years ago) [1, 2]. Many buffalo remains belonging to the Neolithic and Bronze Ages have been discovered, and these remains were morphologically identified as "*Bubalus Mephistopheles*", but DNA analysis revealed that "*Bubalus Mephistopheles*" has no genetic relationship with modern domesticated buffaloes [3]. Genetic evidence suggests that river buffaloes originated in northwestern India and later spread to other regions [4, 5]. Analysis of the complete sequence of the mitochondrial DNA D-loop region confirmed that swamp buffaloes were likely first domesticated in the lower reaches of the Yangtze River, with one lineage migrating upstream to southwestern China, while the rest migrated to southeastern China or through Guangxi to Southeast Asia [5]. China currently has 30 buffalo breeds, including 27 local breeds such as Haizi buffalo, Shanghai buffalo, etc. [6]. There are also three introduced breeds: Murrah buffalo, Nili-Ravi buffalo, and Mediterranean buffalo. These 30 buffalo breeds are mainly distributed in 19 provinces and regions across the country. However, these breeds do not include buffalo breeds from Taiwan and Shandong [7]. Domesticated buffaloes are important agricultural animals in tropical and subtropical regions. Based on differences in body size, appearance, physiological characteristics, and chromosome karyotypes, they can be divided into swamp buffaloes (*B. bubalis carabensis*, chromosome number 2n=48) and river buffaloes (*Bubalus bubalis*, chromosome number 2n=50) [8, 9]. Among the existing buffalo breeds in China, only four breeds—Binglangjiang buffalo, Murrah buffalo, Nili-Ravi buffalo, and Mediterranean buffalo—are river buffaloes, while the remaining breeds are swamp buffaloes. For a long time, buffaloes in China have been domesticated in rural areas as draught animals, making significant contributions to the development of agricultural productivity. With the improvement of China's mechanization level, buffaloes have gradually shifted from draught use to meat, dairy, and dual-purpose (meat and dairy) breeds. Compared to milk produced by Holstein cows, buffalo milk production is lower, but due to its high protein, high fat content, and rich flavor, it has attracted much attention from consumers, and the market size of buffalo milk is gradually expanding. According to Xinhua News Agency[10], statistics from relevant departments show that in 2018, the processing value of buffalo milk in China was 400 million yuan, rising to 2.2 billion yuan in 2019 and over 6 billion yuan in 2023. Despite the rapid development of the buffalo industry in recent years, its valuation still accounts for a relatively small proportion of China's total animal husbandry output value, indicating significant potential for expansion in the buffalo industry's contribution to China's economy.

2. Buffalo population, buffalo milk and meat statistics and distribution in the country during the last 30 years

China is rich in buffalo resources. According to FAO statistics [10], the total number of buffaloes in China in 2022 was 26,875,100, ranking third in the world after India and Pakistan. Mainly distributed in 19 provinces and regions nationwide, including Guangxi, Yunnan, Guangdong, Guizhou, Hubei, Sichuan, Hunan, Jiangxi, and Anhui province. In 2022, the buffalo milk production was about 2,894,900 tons, accounting for only 7.17% of the total milk production [10]. According to FAO statistics, the total production of animal hides (buffaloes, cattle, goats, and sheep) in China in 2022 was 2,886,100 tons, and the buffalo hide production was 189,800 tons, accounting for 6.57% of the total hide production. In 2022, the production of animal fat (including buffaloes, cattle, camels, pigs, goats, and sheep) was 3,927,200 tons, and buffalo fat was 46,700 tons, accounting for 1.19% of the total animal fat production. In 2022, the production of edible buffalo offal was 204,300 tons, accounting for 3.87% of the total edible offal production of 5,274,400 tons. In 2022, the production of buffalo meat was about 656,800 tons, while the production of cattle meat was 7,191,600 tons, accounting for 8.37% of the total beef production (cattle and buffaloes). There is no relevant data report on the production of buffalo milk cheese and butter. See Figures 1, 2, and 3 for the statistical data (source: FAO, 2024) on buffalo population, buffalo milk, and buffalo meat in the past 30 years.
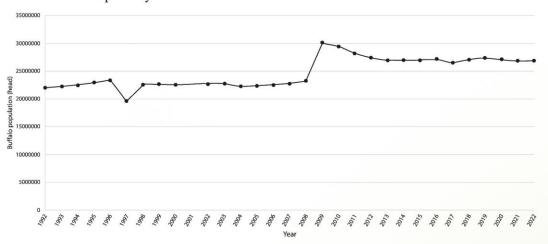
Figure 1: The population of buffalo in China from 1992 to 2022.
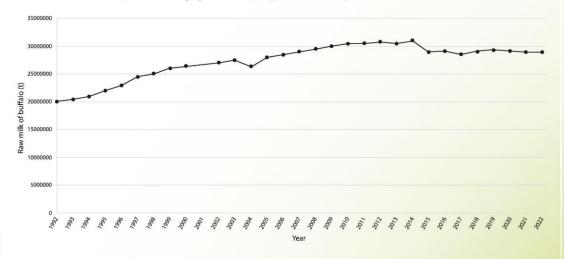
Figure 2: The production of buffalo raw milk in China from 1992 to 2022.
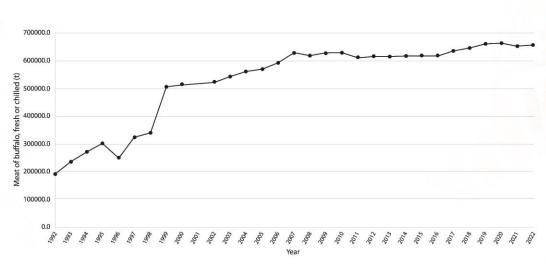
Figure 3: The production of buffalo meat in China from 1992 to 2022.

3. Buffalo farming system/production system - now and in the past
There are four buffalo breeding models in China [11]:

(1) Farmers' breeding model

Tens of thousands of rural households raise buffaloes, generally one to three heads. They are mainly raised through grazing and artificial feeding, fed with crop by-products without adding refined feed, and are mainly used for labor.

(2) Community-based breeding model

Currently, government policies encourage the adoption of standardized buffalo breeding communities. These government-led communities are specifically planned, managed, and constructed, and only qualified applicants are allowed to enter and raise buffaloes. Each community has a buffalo population of 100 to 300 heads. Unique breeding, disease prevention and control, and feeding methods are implemented in these communities. Product sales and purchases are fully implemented at the community level. Under this model, both the quantity and quality of buffalo milk have been significantly improved. More importantly, this model is more conducive to organizing farmers to understand and penetrate the market, improve the overall efficiency of buffalo breeding, and is also a transition towards large-scale breeding methods. However, issues with the community-based breeding model include uneven management levels, unreasonable distribution, and potential environmental pollution.

(3) Intensive farming model

As the buffalo industry develops, small-scale breeding cannot guarantee the supply of buffalo milk. Therefore, large-scale buffalo farms have begun to emerge. Such buffalo farms have a herd size of about 500 to 2,000 heads. Intensive farms can provide advanced breeding management and use mechanical equipment for daily operations, which can increase milk production and quality, reduce production costs, and increase the efficiency of buffalo breeding. However, large-scale farms require more capital investment and involve greater risks. Currently, there are only a few intensive buffalo farms in China.

(4) National buffalo breeding farm

The only national buffalo breeding farm is located in the Guangxi Buffalo Research Institute. It has a buffalo population of about 1,000 heads, including Murrah buffalo, Nili-Ravi buffalo, Mediterranean buffalo, and some local hybrid breeds. It provides buffalo bulls and frozen semen nationwide and is also an important scientific research base for buffalo science research.

4. Nutrition and health care service for the buffalo

Southern China enjoys a subtropical monsoon climate, characterized by warmth, humidity, and abundant resources of forage, crops, and fruits and vegetables. Buffaloes are raised in a relatively extensive manner, utilizing a wide range of common roughage sources such as elephant grass, corn stalks, alfalfa hay, cassava residue, beer residue, pineapple peels, peanut vines, and bean pulp, with roughage as the primary feed and concentrates as the supplement. The formulation of buffalo diets is based on the availability of raw materials at different breeding sites.

In terms of buffalo disease prevention and control, a comprehensive biosecurity system is established, focusing on preventing and controlling major diseases such as brucellosis, tuberculosis, and foot-and-mouth disease. Efforts are accelerated to purify diseases in buffalo core breeding farms and bull stations, creating disease-free zones, areas, or demonstration farms. Tuberculosis and brucellosis screening and prevention measures are conducted for all buffaloes in the farm every six months, as required by the government. In addition to tuberculosis and brucellosis screening and prevention, vaccination is usually conducted based on the prevalence of common buffalo diseases in each region. In addition, farmers and breeding enterprises generally purchase dairy buffalo breeding insurance subsidized by the central government to guard against possible risks of accidental death.

5. Buffalo breeding and improvement system in the country

(1) Breed Introduction

In June 1957, China purchased 55 Murrah buffaloes from India. In 1993, the National Dairy Development Board and the National Dairy Research Institute of India donated 300 straws of Murrah buffalo semen from four pedigrees. In 1995, the National Dairy Development Board donated another 2,000 straws of Murrah buffalo semen from four pedigrees. In 1973, during Premier Zhou Enlai's visit to Pakistan, President Benazir Bhutto donated 50 Nili-Ravi buffaloes, with 25 allocated to Hubei and 25 to Guangxi. In 1999, China imported 5,214 straws of Nili-Ravi buffalo semen from Pakistan, totaling 16 pedigrees. In 2007, the Guangxi Buffalo Research Institute first imported 10,700 straws of Mediterranean buffalo semen from Italy. In 2015, Guangxi Huaxu Company and Hubei Livestock and Poultry Breeding Center separately imported 59 (10 bulls and 49 cows) and 45 (cows) Mediterranean buffaloes from Australia. On June 8, 2024, 5,000 imported frozen embryos of high-quality Pakistani dairy buffaloes were received.

(2) Hybrid Improvement

Guangxi and other provinces in China began buffalo hybridization experiments in the late 1950s, using Murrah bulls. Over time, more provinces participated, and by 1984, the number of hybrid buffaloes nationwide increased significantly. Some provinces continued this effort with government support. From 2006, dairy buffalo breeding subsidies were implemented, with Guangxi and Yunnan as pilot areas. The scope expanded, reaching nine provinces by 2010. Guangxi and Yunnan are key regions in southern China's dairy buffalo industry, with rapid growth in dairy buffalo numbers and a distinct advantage in breeding sources. The buffalo breeding system has improved, leading to increased pregnancy rates and calf births.

(3) Genetic Improvement Plan

On November 30, 2011, the General Office of the Ministry of Agriculture and Rural Affairs issued the National Beef Cattle Genetic Improvement Plan (2011-2025). Subsequently, a new round of the National Animal Genetic Improvement Plan was notified, with a key task being to revise and update the National Beef Cattle Genetic Improvement Plan (2021-2035). This includes: implementing buffalo artificial insemination based on local conditions, enhancing utilization of quality breeding stock, conducting body type evaluation, expanding buffalo milk production performance testing, improving the buffalo production performance measurement system, formulating and perfecting the selection index for Chinese buffaloes, focusing on basic selection and breeding work, utilizing imported high-quality dairy buffalo breeds to improve meat and milk production, supporting regional characteristic buffalo industries, and

strengthening bio-security prevention and control systems, with emphasis on major diseases like buffalo brucellosis, tuberculosis, and foot-and-mouth disease. With advancements in molecular genetics, genetic modification, and sequencing technologies, dairy buffalo breeding is evolving from conventional crossbreeding to a combination of conventional and molecular breeding techniques.

6. Marketing of buffalo and buffalo products

China's buffalo milk industry is mainly concentrated in the southern region, with 22 dairy product manufacturers in Guangxi alone, 10 of which are above a certain scale, including Royal Group Co., Ltd. etc. Buffalo milk products are diverse, including over 20 varieties such as pasteurized buffalo milk, yogurt, UHT milk, cheese, and milk beverages. Changes in consumption patterns have significantly influenced the layout of enterprises' sales channels. Some believe that offline purchases now account for 50% or 60% of the main business, while online sales account for around 40%, indicating that Chinese retail channels are gradually returning to offline sales. Specialty regional direct-sales stores, community-specific direct-sales stores, and specialized milk stations etc. are all actively being built by dairy companies, reflecting a diversified trend in consumer retail.

7. Future buffalo improvement program of private and public sector

Despite rapid development, China's buffalo milk industry faces challenges such as poor germplasm, feed scarcity, low milk yield, waste and emissions from farming, and brand/quality issues. Under government guidance and relevant policies, the buffalo industry pursues green, low-carbon development, scientifically plans livestock breeding zones, delineates prohibited areas, accelerates modern facility animal husbandry, and enhances stable, safe livestock product supply. It also implements strategies to boost buffalo quantity and quality, expands production scale, supports importing high-quality dairy buffalo germplasm from countries like Pakistan, encourages enterprises to expand globally, establish overseas R&D centers, and form innovative consortia tackling dairy buffalo breeding challenges. Additionally, it promotes research on crop straw and agricultural by-product utilization as feed, special forage development, precise evaluation of local buffalo germplasm and dairy buffalo DHI, supports buffalo milk deep processing technology R&D, develops unique buffalo dairy products, and formulates and improves standards for dairy buffalo feeding, raw milk production, processing, and product technical specifications. Future technological advancements may bolster buffalo milk's position in the dairy market. To tackle challenges in the buffalo dairy industry, collaboration and technological innovation among the government, research institutions, and breeding enterprises are crucial to enhance breeding efficiency, product quality, and promote industry health.

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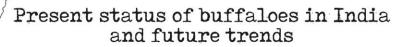
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Present status of buffaloes in India and future trends

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Abstract

India stands as a pivotal player in global agriculture, significantly contributing to the world's milk production and animal product exports. With a substantial livestock population and progressive government policies, India is poised to enhance its agricultural outputs and economic growth. The country's robust buffalo farming and dairy sectors are crucial to its agricultural economy, contributing 24% to global milk production and producing 230.58 million metric tonnes (MMT) of milk in 2022-23, with buffalo milk accounting for 45% of the total. Buffalo meat exports reached 1.55 million tonnes (MT) in 2023, with a forecasted increase to 1.64 MT in 2024. The top five milk-producing states, Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat, and Andhra Pradesh, collectively contribute 53.08% of India's total milk production. Government initiatives, such as support for dairy development and technological advancements in milk procurement networks, have bolstered the sector. The National Dairy Development Board (NDDB) aims to increase India's share in the global milk market, targeting Southeast Asia, Sri Lanka, Bangladesh, and West Asia. India's milk production has grown at a compound annual growth rate (CAGR) of 6%, compared to the world average of 2%. Despite challenges like the need for unconventional feed resources and aflatoxin contamination, initiatives like Dairy Connect, which focus on better feeding, breeding, and disease prevention, offer improvement opportunities. Buffaloes, integral to India's livestock sector, produce about 45% of the nation's milk and are pivotal in meat production, with India being the third-largest exporter of buffalo meat globally. Their ability to thrive in diverse agro-climatic conditions and support smallholder farming systems underscores their importance in rural income and poverty reduction.

Buffalo population, milk, and meat statistics and distribution

Over the past 30 years, India's buffalo population has shown a steady increase. According to FAO and government sources, the buffalo population has grown from approximately 84 million in the 1990s to over 115 million in recent years. Buffalo milk production has also surged, with current estimates indicating that buffaloes contribute 45% of the total milk production, amounting to Buffalo farming system/production system around 104 million metric tonnes. In terms of meat production, India exported 1.55 million tonnes of buffalo meat in 2023, with a projected increase to 1.64 million tonnes in 2024.

Historically, buffalo farming in India was characterized by extensive and transhumant systems, where buffaloes grazed on communal lands. Over time, the farming systems have evolved into semi-intensive and intensive commercial farming. The modern buffalo farming system includes better management practices, improved housing, and advanced feeding strategies. This transition has been driven by the need to increase productivity and meet the growing demand for milk and meat.

Institutional Research in Buffalo Production Systems in India

India's buffalo production systems have witnessed significant advancements through the concerted efforts of various research institutions under the Indian Council of Agricultural Research (ICAR) and numerous state Veterinary and Animal Sciences Universities. The ICAR-Central Institute for Research on Buffaloes (ICAR-CIRB), Hisar, is a premier institution dedicated solely to buffalo research. It focuses on genetic improvement, reproductive technologies, nutrition, and health management. Recently, the Institute has initiated efforts towards incorporating precision farming practices in buffalo production using buffalo-specific sensors. The ICAR-National Dairy Research Institute (ICAR-NDRI), Karnal, is a leading institution in dairy research, contributing extensively to buffalo production through the development of balanced feed formulations and unconventional feed resources, addressing nutritional requirements, and improving milk yield. ICAR-Indian Veterinary Research Institute (ICAR-IVRI), Bareilly is the premier

Institute working of different aspects of animal health and production. Among state universities, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana, and Lala Lajpat Rai University of Veterinary and Animal Sciences (LUVAS), Hisar, focus on comprehensive research and extension activities related to various aspects of buffalo production systems. Several other universities across India also contribute to buffalo research and extension, including Tamil Nadu Veterinary and Animal Sciences University (TANUVAS), and Maharashtra Animal and Fishery Sciences University (MAFSU). These institutions conduct extensive field trials, workshops, and training programs, ensuring that the latest research and technologies reach the farming community.

Buffalo breeding and improvement system in the country

India has implemented several breeding programs aimed at improving buffalo productivity. These programs include selective breeding, artificial insemination, and the use of high-quality semen from genetically superior bulls. Notable buffalo breeds like Murrah, Jaffarabadi, and Mehsana have been the focus of these programs due to their high milk yield and adaptability. The government's support, through institutions like the ICAR-Central Institute for Research on Buffaloes (CIRB), has been crucial in advancing these breeding initiatives.

Marketing of buffalo and buffalo products

The marketing of buffalo products, especially milk and meat, has expanded significantly. The liberalization of the dairy sector in 2002 allowed private investment, leading to the growth of organized milk procurement and processing. The formal sector, comprising cooperatives and private companies, now competes with the informal sector, which still dominates milk distribution in many regions. Buffalo meat exports have also seen a substantial rise, driven by demand from international markets such as Southeast Asia and the Middle East.

Government initiatives and Future buffalo improvement program of private and public sector

The Government of India has implemented various initiatives to support buffalo farming and the livestock sector, focusing on sustainable development, genetic improvement, and disease control to enhance productivity and profitability for farmers. Key programs include the Rashtriya Gokul Mission (RGM), which promotes the conservation and genetic improvement of indigenous cattle breeds like Murrah buffaloes through scientific practices; the National Livestock Mission (NLM), aimed at sustainable livestock development and employment generation; and the National Programme for Dairy Development (NPDD), which consolidates earlier schemes to advance the dairy sector. The Dairy Infrastructure Development Fund (DIDF) and the Animal Husbandry Infrastructure Development Fund (AHIDF) provide financial assistance for infrastructure enhancements, supporting disease control, processing, and value chain improvements. The National Animal Disease Control Programme (NADCP) targets diseases like Foot and Mouth Disease (FMD) and Brucellosis through widespread vaccination, while the Supporting Dairy Cooperatives & Farmer Producer Organizations (SDCFPO) scheme offers working capital loans to stabilize market access and ensure timely payments to farmers.

Future improvement programs aim to enhance buffalo productivity through advanced breeding techniques, better nutritional management, and improved healthcare services. Public sector initiatives, supported by the National Dairy Development Board (NDDB) and CIRB, focus on genetic improvement and sustainable farming practices. Private sector investments are expected to drive technological advancements and market expansion. Collaborative efforts between government and private entities will be crucial in addressing challenges such as climate change vulnerability, delayed puberty, and precise detection of estrus in buffaloes.
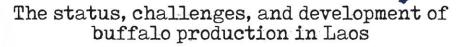
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The status, challenges, and development of buffalo production in Laos

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Abstract

In Lao PDR, the buffalo is important for small and marginal farmers' livelihoods and economic development as a source of food, work animals, and tourist attractions. Therefore, buffaloes needed an in-depth study to examine the challenges and opportunities for buffalo development in Laos. The buffalo population in Laos has significantly increased by an average of 4.2% per year from 2018 (1,200,040 heads) to 2023 (1,250,174 heads). The most proportionate increase from 2018 to 2023 has occurred in the Northern regions, where buffalo numbers have increased by 11.4%, in the central region by 4.1%, and in the southern region by -1.9%, respectively. There are three types of farm systems: extensive, intensive-commercial, and semi-intensive. The buffalo population was slowly increasing due to slow breeding, and the mortality rate of buffaloes is generally high. Buffaloes are generally spread in various agroclimatic conditions, which has led to the development of breeds or strains adapted to specific environmental conditions. Crossbreeding took place only on one dairy buffalo farm. Therefore, the government must implement research on the potential and challenges of buffalo in Laos. It is vital to have a thorough understanding of local markets, social structures, and neighboring countries before providing new policies to smallholder farmers.

Keywords: Dairy buffalo, production system, markets, farm system, Lao PDR.
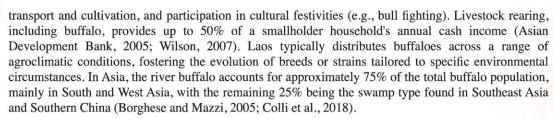
Importance of buffalo in the livestock sector, agricultural sector and national

Lao People's Democratic Republic (Lao PDR or Laos) is a land-locked country centrally located in the Greater Mekong Subregion (GMS), sharing borders with five countries: China to the north, Myanmar to the north-west, Thailand to the west, Vietnam to the east, and Cambodia to the south. Laos comprises multiple ethnic groups and in 2023 had an estimated population of 7.6 million people (LAOSIS, 2023). However, the country can be divided into the Northern Region (upland or sloping lands), the Central Region (lowland), and the Southern Region. These provide different challenges and opportunities for development, particularly buffalo production. Agriculture in the Mekong areas is becoming more and more market-oriented, with the market driving the process of agricultural intensification and diversification. Upland villages in the sloping land zone are more remote, have poorer road and market access, and villagers rely predominantly on subsistence farming. While the Mekong Corridor has significantly reduced poverty, economic growth has bypassed the people in the sloping land zone, leaving many of them still living in poverty. Therefore, the Ministry of Agriculture and Forestry (2010) notes that a large majority of the population relies on agriculture and uses natural resources for their livelihoods. They engage in livestock, fishery, and forestry activities, contributing approximately 20.3% of the total national Gross Domestic Product (GDP) of 4.7% and employing approximately 35.2% of the national and international workforce in 2024. However, Laos's increasing food security, improving nutrition, and reducing poverty remain complex challenges.

Laos has large livestock populations, contributing greatly to international livestock biodiversity. Therefore, the estimates from the Central Statistical Agency of Laos indicate that the country has approximately 1,250,174 buffaloes, 2,561,453 beef cattle, 4,539,785 pigs, 801,378 goats and sheep, 51,972,665 poultry (LAOSIS, 2024). Among many livestock species, buffalo or large ruminant livestock production in Laos, particularly smallholder farming systems, which is increasingly important, providing animals and meat for sale or consumption, storage of wealth, fertilizer for crops, draught power for

transport and cultivation, and participation in cultural festivities (e.g., bull fighting). Livestock rearing, including buffalo, provides up to 50% of a smallholder household's annual cash income (Asian Development Bank, 2005; Wilson, 2007). Laos typically distributes buffaloes across a range of agroclimatic conditions, fostering the evolution of breeds or strains tailored to specific environmental circumstances. In Asia, the river buffalo accounts for approximately 75% of the total buffalo population, mainly in South and West Asia, with the remaining 25% being the swamp type found in Southeast Asia and Southern China (Borghese and Mazzi, 2005; Colli et al., 2018).

However, there are multiple constraints to more modern and optimal production techniques and productivity, including limited availability of land, underfeeding practices with poor quality fodder, major transboundary and endemic disease issues, poor husbandry knowledge, minimal agricultural extension capacity with a lack of knowledge transfer, a low capacity animal health reporting and response system with suboptimal disease surveillance and few outbreak investigations, minimal confirmation of disease diagnoses, and poor disease prevention and control management (Windsor, 2011). Therefore, the policy not specific to buffaloes in Laos constrains many smallholder buffalo farms, particularly these constraints on production attitudes and practices, which decrease the ability of many Laos farmers not to achieve optimal production and increase their vulnerability to genetic, disease, and climate shocks affecting their livestock.

Buffalo population, buffalo milk and meat statistics and distribution in the country

Buffaloes are frequently utilized as draft animals for paddy fields, providing animals and meat for sale or consumption, storage of wealth, fertilizer for crops, cultural festivities, and smallholder households' annual cash income. However, despite their substantial importance to the national economy, there have been slowly growing concerns about the buffalo population. Specifically, the buffalo population in 2018 was 1,200,040 heads, which slightly increased to 1,250,174 heads in 2023.

Table 1: The trend for the buffalo population in Laos from 2018-2023.

Buffalo population (heads/year)						
Region	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Northern Region	285,087	291,000	295,225	314,742	316,630	317,580
Central Region	586,294	596,000	601,550	604,639	608,267	610,093
Southern Region	328,658	335,000	337,400	319,620	321,538	322,501
Total	1,200,040	1,222,000	1,234,175	1,239,001	1,246,435	1,250,174

The buffalo population in Laos is currently about 1.25 million head (Table 1), an increase of 0.3%. Buffaloes are mainly in the Central Region 49%, with 25% in the Northern Region and 26% in the Southern Region. The most proportionate increase from 2018 to 2023 has occurred in the northern regions, where buffalo numbers have increased by 11.4%, in the central region by 4.1%, and in the southern region by -1.9%, respectively.

Buffalo milk is only on one farm in Laos; this farm is shared- ownership by Australians and Americans. It began in 2017 with 10 buffaloes and was rented from smallholder farmers nearby. However, the dairy buffalo farm raised about 91 buffaloes (Murrah buffalo 19 heads, crossbreed buffalo 20 heads, and swarm buffalo 52 heads), and after the pregnant buffalo was returned to the farmer with 100 US dollars to take care of the buffalo before giving birth, a calf buffalo were engaged by the village farmers, and 19 milking buffaloes were engaged in the dry-season. The fresh milk on the farm was about 40 L/day, and there would be high lactation from November, about 60-80 L/day. Milk is processed into yogurt, cheese, mozzarella, and ice cream, sold at the farm shop for tourists, and sent to hotels and restaurants in Luangprabang. Buffalo milk significantly impacts human nutrition because it contains more essential nutrients than cow

milk. Individuals with bovine milk allergies can consume buffalo milk without experiencing adverse reactions. Buffalo milk has elevated levels of lipids, lactose, protein, casein, and arsenic (Garau et al., 2021; Abd El-Salam, and El-Shibiny, 2011). Although the cholesterol content of buffalo milk is lower than that of cow milk, it delivers more energy per unit volume of milk. It is a rich source of iron, phosphorus, vitamin A, and tocopherol (a natural antioxidant). However, unlike raw cow milk, raw buffalo milk is not widely consumed (Abesinghe et al., 2020; Vargas-Ramella et al., 2021). However, the dairy buffalo farm in Laos has plans to export cheese and mozzarella to Japan and China.

Buffalo farming system, production system - now and in the past

Buffalo productions stayed the long traditional life for smallholder farmers in rural livelihoods throughout the transition from a more self-sufficient peasant economy to a mixed commercial-subsistence economy. The main purpose of farmers is to slaughter, consume, and sell buffalo for several reasons. Buffalo are offered opportunities for exchange with outsiders for money or other articles. Moreover, buffalo meat was valuable in preparing feasts for guests in Laos's peasant society, agricultural labor exchanges, life passage rituals, and village festivals. Furthermore, buffalo meat was offered to various spiritualities. However, intensive or commercial buffalo farming increased from 6 farms (with 723 buffaloes) in 2018 to 39 farms (with 2,299 buffaloes) in 2023. Therefore, 1,247,875 buffaloes in the feeding system can be grouped into three types: fully grazing (extensive), cut and carry (intensive-commercial), and grazing during the day and feeding at night (semi-intensive).

Buffalo grazing and fallow land in rural areas of northern Laos, land remaining fallow after the harvest of both paddy and by-pass agriculture is used for grazing buffaloes were allowed to move together freely across the field, animals can move in groups, and each group had a leader by the full age of the male buffalo. However, small-scale or backyard producers grazed freely on roadsides, grassland, and the paddy field after harvesting during the day and returning home later in the day to the nearby villages. When rice transplanting started, the farmers were moved from the paddy fields to the forest campus, according to villagers or secondary forest. Lao grass field, bush, or young woods that have been fallowed for between one and four years after swidden cultivation are appropriate for grazing lands. The grazers selected points near streams or ponds where plants such as Napier, Ruzi, Beauv. (Nya Kha), or bamboo grew in bunches and let their water buffaloes graze in these areas during the wet rice planting season.

Table 2: The number of buffalo farms and number of exported.

Buffaloes	2018	2019	2020	2021	2022	2023
Farms	6	9	28	28	25	39
Animal (head)	723	1,107	1,550	1,643	1,625	2,299
Buffaloes exported	14,300	12,000	20,000	45,840	36,600	23,250

Table 2 shows that the number of buffaloes in farms that were registered and approved by the Ministry of Agriculture and Forestry was slowly increasing, as shown by the fact commercial buffalo farming increased from 6 farms (with 723 buffaloes) in 2018 to 39 farms (with 2,299 buffaloes) in 2023. On the other hand, Napasirth, P. and N, Viengsakoun (2018) reported 170 commercial cattle farms in 2016 and only 3 years of commercial cattle farms, a significant increase of 26% in 2021. The important factor to success is that under an intergovernmental agreement in 2017, China gave Laos an export quota of 500,000 cattle.

Nutrition and health care service for the buffalo

Buffaloes spend most of the day grazing and return to the stables in the evening and/or nighttime, limiting the farmers' ability to monitor their health. Currently, the farm systems, nutrition, and health care services

are the main factors limiting the increase in buffalo production in Lao PDR, as shown by the fact that the number of buffalo farms is slowly increasing and few buffalo are fattened for sale closer to markets. However, in the Mekong Corridor, available feed resources are limiting the expansion of buffalo production, particularly in areas where irrigation enables farmers to grow rice crops and other dry-season crops. However, there have been few documented studies on smallholder buffalo production under the free-grazing system in Laos until recently, when 500 local buffalo were enrolled in a longitudinal study and production data including body weight, average daily gains (ADG), calving rate, and calving interval were measured between 2008 and 2011 (Nampanya et al., 2013). Nampanya et al. (2014) established baseline production parameters of northern Lao smallholder buffalo, providing evidence of low mean weight (325-357 kg) and ADG (86-96 g/d). It confirmed that high variations occurred in body weights and ADG between seasons, reflecting the dramatic seasonal availability of feed resources, with animals in a negative energy balance during the dry period season from December to May (Nampanya et al., 2013; Stür et al., 2002). A recent on-farm fattening trial demonstrated a significant difference in ADG between the fattened and free-grazed buffalo, with fattened animals having an ADG of approximately 216 g/d, three times greater than those free-grazed (Nampanya et al., 2013). Further investigation of methods to improve nutritional and feeding management, including silage preservation of forage for buffalo calves pre- and post-weaning is recommended by Nampanya et al. (2014).

Health care service for the buffalo, along with feed deficiency in the dry season, the high prevalence of endemic diseases such as Foot and Mouth Disease (FMD), Haemorrhagic Septicaemia (HS), and internal parasites including *Toxocara vitulorum* and *Fasciola gigantica* causing Toxocariasis and Fascioliasis, respectively, are considered the most important diseases impacting cattle and buffalo production in Laos (Stür et al., 2002; MOAF, 2008; Nampanya et al., 2013: Windsor et al., 2008). However, the frequent endemic diseases in buffalo indicate low vaccination coverage. More significantly reflects the widespread poor biosecurity practices that reflect the low levels of farmer knowledge of infectious disease. Biosecurity includes all the hygienic practices designed to reduce the risk of infectious agents entering a herd, spreading within a herd, or entering and spreading within and beyond a country (Larson, 2008). Importantly, the introduction of village-level biosecurity practices should be conducted at an appropriate pace using a participatory approach to ensure the acceptance and sustainability of the programs (Nampanya et al., 2010). Depending on vaccine availability, vaccinations for FMD and HS should be implemented twice per year in May-June and November-December, as these were identified as high-risk periods for the disease infection (Nampanya et al., 2013, De Alwis, 1999). Although treatment for T. vitulorum infestation is not expensive or inconvenient (Rast et al., 2013; Starke-Buzetti, 2006) many smallholder farmers tend to forget this practice; hence, the repetition of extension messages focused on the calving season between November and March is recommended (Nampanya et al., 2013).

Buffalo breeding and improvement system in the country

Traditional agricultural practices contribute to low productivity because buffaloes are released on land that has been used since livestock existed, natural feed is still relied upon, and it is highly uncommon for breeders to use plant forage reserves for animal feed. The increase in the buffalo population is insignificant because breeders who practice such maintenance systems pay little attention to animal health, rely on natural mating, and use inefficient recording (Nampanya et al., 2014). The buffalo population is slowly increasing due to slow breeding, and due to the mortality rate of buffaloes attained sexual maturity at 2 and 24 months, according to reports, traditional Lao buffaloes calve at a rate of 41-52%. The puberty stage lasts 19-21 months, and the first calf is born between the ages of 4 to 5 years. The gestation period is about 10 and a half months, or approximately 316 days (Nampanya et al., 2014). The leading cause of low buffalo productivity is the adult female buffalo's lack of intense maintenance, lack of recording, and occurrence of silent heat. As a result, reproduction management becomes inefficient. Inefficient feeding nutrition and a lack of feed availability also impact reproductive and productive performance by delaying the resumption of the estrous cycle, increasing the calving interval, and reducing the growth rate (Windsor, 2011). Despite breeding inefficiencies, and keeping a good policy, the populations of buffaloes

are expected to contribute to the development of buffalo farming in Laos. Therefore, dairy buffalo farms model breeding by renting the buffalo from the farmers to milk them and, in the process, crossbreeding them with the Murrah buffalo that the Chinese government had brought in to make bigger, stronger, healthier buffalo, and make them better milk as well. Local swamp buffalo only provide about 2.5 liters a day, so when they get to the mini-farm for drying off, they only give a few hundred grams of milk a day. Then return all the buffalo when they are between 3-4 months pregnant, and with better genetics on board after six months of milking, we move the mother from the dairy side of the farm to the tourist mini-farm.

Marketing of buffalo and buffalo products
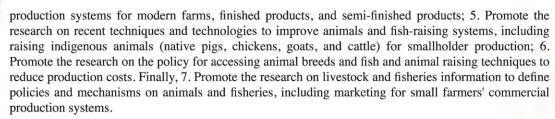
Buffalo meat is considered a complement or substitute to beef, thus emphasizing its essential role in supplementing national protein needs. Currently, buffalo in Laos is more important for economic change. Human health concerns could increase demand for buffalo products because they contain essential compounds such as high protein, iron, and CLA. Promotion and development of smallholders' support for buffalo production using local feed resources should be encouraged and recommended to achieve potential production and profitability (Wanapat and Chanthakhoun, 2015). The Lao National Strategy for Agricultural Development focuses on the sustainable development of food and income security, emphasizing the need to increase livestock production to reduce poverty, increase protein consumption from 22 to 50 kg per person in rural areas and from 33 to 70 kg per person in urban areas, and increase total meat supply to 40-50 kg per capita per year at 5% growth per annum (Ministry of Planning and Investment, 2011). Achieving this goal is a major challenge, and it is considered that a systems approach with multiple interventions will be required. However, the development of a regional road network throughout the GMS has enhanced the increasing demand for meat in both domestic and neighboring markets, China and Vietnam in particular (ADB, 2005), and the export price of live buffalo from Laos has seen a steady increase over the past five years. In 2012 and 2013, the export price per kilogram was 0.78 US dollars. However, this increased to 1.73 US dollars in 2017, 1.41 US dollars in 2018, 1.94 US dollars in 2019, and 2.02 US dollars in 2020 (https://www.selinawamucii.com/insights/prices/lao/ live-buffalo/), and in 2024 it increased more because of inflation. The approximate wholesale price range for Laos live buffalo is between US$ 2.41 and US$ 3.92 per kilogram, which, at 1,200 to 2,000 $/head as a good income as much as the average 50-60% annual salary in Laos, used to act as something of an insurance policy for locals as the fund for their children's school fees, paying medical bills, or even financing weddings.

The first buffalo dairy farm in Laos had a goal that has always been to be environmentally friendly and use local buffalo by renting animals that is already being raised in the villages. At the end of the rental period, the farmer is paid a lump sum depending on how many days the buffalo milk is used, approximately $100 per buffalo. The products of milk in the dry season is the fresh milk on the farm, which is about 40L/day, and would be high lactation from November, which is about 60-80L/day. Processing to the menu includes bocconcini, ricotta, blue cheese, feta, burrata (by request), yogurt, and their most popular type of cheese, ice cream to sell in the farm. Hotels in nearby Luang Prabang, like La Résidence Phou Vao, A Belmond Hotel, and soon, Avani+ Luang Prabang and Rosewood Luang Prabang, can also try Laos Dairy Farm's cheese at the breakfast buffet and in the hotel restaurants. The more hotels and restaurants that purchase from the dairy buffalo farm and the more tourists that come to the farm and try the products, the more farmers can work with to get local buffalo milk.

Future Buffalo improvement program of private and public sector

In the agriculture development strategy for 2025 and the vision for 2030 (MAF, 2015), the Laos government indicated some measurements to support commercial livestock production research, such as: 1. Promote research on the conservation of local animals and fish genetic resources and improve them to supply meat for commercial purposes; 2. Research to improve varieties, and products and expand animals for breeding that have commercial potential, such as indigenous crossbred cattle, pigs, and goats; 3. Promote research on improving production systems and supplying animal breeds for commercial purposes; 4. Promote research on adaptation of advanced technologies to improve animals and fishery

production systems for modern farms, finished products, and semi-finished products; 5. Promote the research on recent techniques and technologies to improve animals and fish-raising systems, including raising indigenous animals (native pigs, chickens, goats, and cattle) for smallholder production; 6. Promote the research on the policy for accessing animal breeds and fish and animal raising techniques to reduce production costs. Finally, 7. Promote the research on livestock and fisheries information to define policies and mechanisms on animals and fisheries, including marketing for small farmers' commercial production systems.

In Laos, economies develop, and income rises but is affected by inflation. However, the demand for buffalo products increases, middlemen often transfer buffaloes to wholesale and retail markets, and smallholder farmers have no incentive to invest in improving the quality of buffalo farms. This puts a serious constraint on the economic benefits producers and the government must focus on semi-intensive or intensive-commercial action policies to make the farm more on the list and control the threat to buffalo health, nutrition, breeding, and conservation programs for food security and safety buffaloes in the country, essential quality characteristics from a public health perspective for demand and export to another country. In the agriculture development strategy for 2025 and the vision for 2030 (MAF, 2015), policies not focused on could enhance market access and participation in the sustainability of livestock production, only cattle was more successes under an intergovernmental agreement in 2017. China gave Laos an export quota of 500,000 cattle, not any policy focused on buffalo. Therefore, the government must implement research on the potential and challenge of buffalo in Laos. It is vital to have a thorough understanding of local markets, social structures, and neighboring countries before providing new policies to smallholder farmers.

Conclusions

Based on this review, it could be concluded that the majority of buffaloes are mainly in the Central Region 49%, with 25% in the Northern Region and 26% in the Southern Region of buffalo. However, intensive or commercial buffalo farming increased from 6 farms (with 723 buffalos) in 2018 to 39 farms (with 2,299 buffalos) in 2023 still low number. Therefore, 1,247,875 buffaloes in the feeding system can be grouped into three types: extensive, intensive-commercial, and semi-intensive. The buffalo population is slowly increasing due to slow breeding, and the mortality rate of buffaloes. The government must implement research on the potential and challenge of buffalo in Laos. It is vital to have a thorough understanding of local markets, social structures, and neighboring countries.

Acknowledgment

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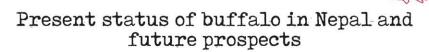
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COUNTRY PAPER

Present status of buffalo in Nepal and future prospects

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Ecological description of Nepal

Nepal is a land-locked country nestled in the foothills of the Himalayas. Nepal covers an area of 147,181 sq. km (between 80° 4' and 88° 12' East and 26° 22' and 30° 27' North). It is situated in South Asia and surrounded by the Tibetan Autonomous Region of China in the north and by India in the south, east and west. The length of the Kingdom is 880 kilometers east to west, and varies between 150 to 250 kilometers north to south.

Topographically, Nepal is divided into three distinct ecological regions: Mountains, Hills and Terai (or plains) (*Figure1*). The Mountain region ranges in altitude between 4,877 to 8,848 meters above sea level (m asl) and covers a land area of 51817 square kilometers. Because of harsh terrain, transportation and communication facilities in this region are minimal, and only about eight percent of the total population live here. It includes eight of the highest 14 summits in the world which exceed an altitude of 8,000 meters including the world's highest peak Mount Everest. In contrast, the Hill region which ranges in altitude from 610 to 4800 m asl is densely populated. About 45% of the total population of Nepal lives in the Hills which covers an area of 61345 square kilometers. Despite the rugged terrain in this region, the higher population density has led to better development of transportation and communication facilities compared to the mountainous areas. Unlike the Mountains and Hills, the Terai/plain region in the southern part of the country can be regarded as an extension of the relatively flat Gangetic plains. This area which covers 34019 square kilometers is the most fertile part of the country. The Terai region, covering 17 percent of Nepal's area, is a lowland region with some hill ranges and 47% of the population lives here. Due to its relatively flat terrain, this region has more advanced transportation and communication facilities compared to the other two regions of the country, which has attracted emerging industries. The Hilly region, encompassing 68% of the country's area, consists of mountainous terrain without snow. The Himalaya region, covering 15 percent of Nepal's area, contains snow and is home to several high-altitude livestock such as Yak, Chauri, Chyangra goat, Bhyanglung sheep etc. Nepal, with elevations ranging from as less as 64 meters to over 8,000 meters, has eight climate zones from tropical to perpetual snow (wikipedia).

In Nepal, climatic conditions vary substantially by altitude. The climatic condition ranges from the sweltering heat of the Terai in the lowland to the freezing cold in the Himalayan highland. The Terai is the tropical zone where temperatures can go up to 44°C in the summer and fall to 5°C in the winter. The corresponding temperatures for the Hill and Mountain areas are 41°C and 30°C, respectively, in the summer, and 3°C and way below 0°C, respectively, in the winter. The subtropical climate zone ranges from 1,000 to 2,000 meters and the temperate climate zone, from 2,000 to 3,000 meters. Nepal's land cover is dominated by forests, which cover 39.09% of the country's total geographical area, followed by agriculture areas at 29.83%. The hill region constitutes the largest portion of Nepal, with significant cultivated lands, natural vegetation, and is suitable for livestock farming. Forests in Nepal face deforestation due to over-harvesting of firewood, illegal logging, clearing for agriculture, and infrastructure expansion. As of 2010, 64.8% of the forested area in Nepal is covered by core forests of more than 500 hectare in size.
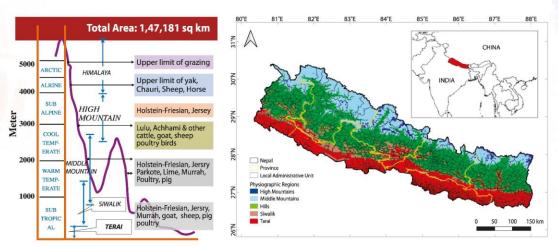
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Figure 1: *Geo-ecological situation of the country.*

Buffalo statistics during the last 20/30 years

The total population, milk and meat production trends of two decades shows that there is slightly increasing trend of total population and milk and meat production (Table 1, Figure 2) until Year 2013/14 when there is slight decrease (MoALD, 2022). Contribution of livestock and buffalo in Agricultural GDP is 25-7% and 11.54%, respectively. In recent years, the population and meat production are again in decreasing due to various reasons. One of the reasons is buffalo meat being one of the common commodities to export while farmers are not willing to raise calves. Furthermore, male members of the family are migrated to earn money while female member, children and old people are left at home which made them forced to abandon buffalo farming and to go for small ruminant and chicken farming.

Table 2: *Statistical information of livestock and poultry (FY 2021/22).*

Parameters	Values
Cattle	7,466,841
Buffalo	5,159,931
Sheep	793,725
Goat	13,442,614
Pig	1,588,838
Poultry	73,418,077
Milking Cattle	1,209,041
Milking Buffalo	1,635,492
Total milk produce	2.47million mt (57.23% from buffalo)
Total meat produce	520 thousand mt (36.13% from buffalo)

Source: MoALD, 2023

Buffalo rearing is common in all over the country. Nearly half of the households of the country keep buffaloes primarily for milk, meat and also for manure, hide, traction and ploughing agricultural land. The buffalo are common in the terai (plain) region followed by mid hills and high hills and mainly raised for milk and nowadays, it is becoming popular for meat.

When comparing for last twenty years' statistics, buffalo population, meat and milk production is in positive trend (Table 3) which is supporting the self-sufficiency in milk and meat requirement of the country.
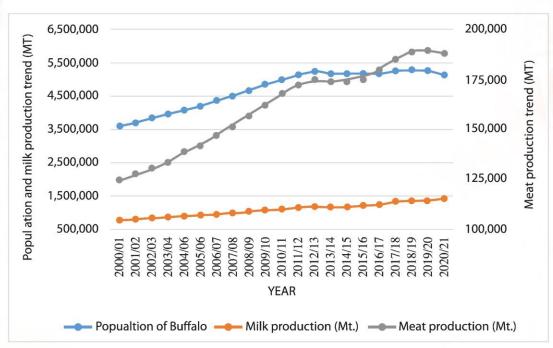
Figure 2: Population and production trend of last decades.

Table 4: Total population, milk and meat production of buffalo in Nepal.

Production	2001/02	2020/21	Change in 20 years (%)	Change/Year (%)
Population	3,700,864	5,159,931	39.43 %	1.971%
Meat (MT)	127,495	188,172	47.6%	2.38%
Milk (MT)	806,690	1,419,412	75.95%	3.8 %

Source: (MoALD, 2022)
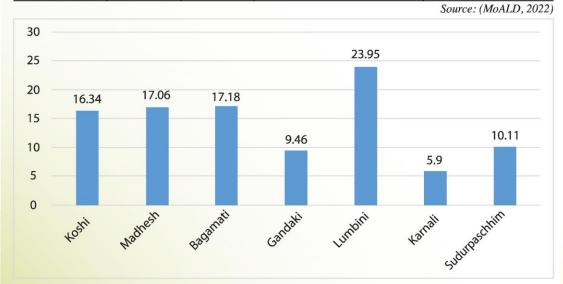
Figure 3: Province-wise buffalo population (MoALD, 2022).

Lumbini province covers maximum 23.95% of population followed by Bagmati province17.18%, Madhesh province 17.06%, Koshi province 16.34%, Sudurpaschhim 10.11%, Gandaki province 9.46% and least in Karnali province 5.90% (Figure 3). Kailali, Banke,Kapilbastu, Bara, Sunsari, Rupendehi and Saptari are the districts in terai region having high buffalo population whereas Manang district in high altitude is only district with no buffalo.

Indigenous Buffalo breeds of Nepal

There are about 5.1 million buffalo in Nepal (MoALD, 2022), of which 65% is estimated to be indigenous and 35% are exotic (either pure or crossbred) breeds (Neopane et al, 2006), Country Report, 2014). Four indigenous buffalo breeds have been identified namely Lime, Parkote, Gaddi, and Terai (Gorkhali et al, 2021; Neopane and Gorkhali, 2008; Sapkota et al., 2017) (Figure 3) and are characterized in phenotypic, chromosomal, and molecular levels and their production performance has been well-documented. Nepal also has a wild population of buffalo which is speculated as the living ancestor of the domestic population of buffaloes (Gorkhali et al, 2021; Dhakal et al, 2024 in press). All identified indigenous and wild population are confirmed to be riverine type with 50 chromosomes.

	Habitat	Morphological characteristics	Productive characteristics	Reproductive characterisitics	Remark
Lime buffalo	River basins to mid hills (up to 1500 m asl) of the western region of the country.	External characteristics resembles to swamp type Grey in color and its skin color shades from whitish brown to grey chevron of grey or white hair below the jaw and around the brisket region.	The smallest amongst indigenous buffalo breeds in terms of body size and weight Average adult weight of this buffalo is 311±1.5 kg. Average daily milk yield: 3.0 liters, Lactation length: 305 days.	Age at first service: 51.6 months, Age at first calving: 61.2 months, Calving Interval: 21.0 months.	Declining
Parkote buffalo	low to mid hills of the western region of the country from an elevation of 500 m asl up to 1500 m asl.	Mainly black in color, but occasionally they are found in brown and light brown color. Horns are sword-shaped directed towards the back of the body.	The average adult body weight of this buffalo is 341.9±1.3 kg. Average daily milk yield: 2.77 liters, Lactation length: 305 days.	Age at first service: 51.8 months, Age at first calving: 62.2 months, Calving Interval: 20.6 months.	Declining

	Habitat	Morphological characteristics	Productive characteristics	Reproductive characterisitics	Remark
Gaddi buffalo	Far western mid to high hill region of the country from an elevation of 1500 masl up to 4500 masl.	Black in color with white round patches on the forehead. Occasionally, they are also found in brown and light brown color. Horns are long half curved.	Adult weight is 452±8.03 kg. Average daily milk yield: 3.5 liters, Lactation length: 420 days.	Age at first service: 45.6 months, Age at first calving: 68.4 months, Calving Interval: 23.4 months	Declining and population at risk.
Terai buffalo	Across terai regions of the country from an elevation of 100 masl up to 500 masl.	Plain hair color pattern with black hair coat color. Mostly and dominantly white tail switch tips. Black colored horn with fixed type horn attachment.	Adult weight is 331±7.9 kg. Average daily milk yield: 1.6 liters, Lactation length: 285 days.	Age at first service: 34 months, Age at first calving: 44 months.	Declining, severely crossed with Murrah.
Wild Water Buffalo	Koshi Tappu Wildlife Reserve: Eastern terai regions of the country at an elevation of 80 masl.	Slate grey to black in color, mature males tend to be very dark. One or two chevron mark or white crescents are usually present on the throat or upper chest and eyes also have pale markings on the side of the nose and by mouth. Large or long scimitar-shaped horns (may exceed 120 cm), semi-circular in shape. Males have thicker horns.	Average adult weight: 800-1200 kg.	Gestation period: 10 -11 months; Inter-Calving interval: 12 months.	Endangered (Total Population is only 432)

Figure 5. Lime, Parkote, Gaddi and Terai (clockwise).

Arnee Female (PC: Smritee Lama)

Arnee Male (PC: Karun Dewan/WWF)

Exotic breeds

1. Murrah buffalo
2. Nili Ravi buffalo

Positive attributes of indigenous buffaloes

Body size of indigenous buffaloes is relatively smaller and sturdier. They, therefore, are highly suitable to thrive on narrow and stiff topographical hills and mountains, which covers about 70% of total area of the country. They are excellently adapted to local harsh environmental conditions in which the depletion of nutritional status has been a continuous feature. These features certainly emphasize the superiority of indigenous buffaloes over the exotic ones and their crossbred which is reflected by resilience in

economically important diseases. Research has already discovered a wide variation in productivity of indigenous buffaloes in terms of milk production showed their unexploited genetic potential (Amatya et al., 2000). Moreover, indigenous buffaloes produce comparatively similar milk yield in comparison to exotic and crossbred animals in traditional farming system. Nonetheless, buffalo covers the major demand of meat in the country as well. The milk production and growth traits of indigenous buffalo in comparison to exotic crossbreds are low.

Buffalo production system

The buffalo production system can be categorized into two systems: traditional subsistence milk production system and market linked commercial/semi-commercial milk production system. Under traditional subsistence production system, majority of the dairy animals are of indigenous origin, are kept in low input and mostly under grazing management with rare uses of external inputs. Under this system animals are kept for milk and milk products mainly for household consumption, and surplus milk if any is sold to local customers or village tea shops. In commercial/semi commercial system, the farmers manage their herds in order to maintain a steady supply of milk. The number of milch animals reared in a smallholder system are variable depending upon the size of landholding, the availability of feed, and human labor. However, in the major dairy pocket areas of Nepal, majority of the dairy farmers are smallholders.

Although both buffaloes and cattle co-exist in a single farm together, the use of buffalo is becoming popular among smallholder farmers because of their adaptability to local feed resources, high milk fat content, and fetch higher value than the cattle milk. In recent times, there has been substantial growth of peri-urban dairies in areas where there is good road link and good market potential for the milk and products in adjoining city center. The animals in this system depend on straw and concentrates, whereas there is a practice of cultivating forage grass depending on availability of land in peri-urban areas. Green grasses from fallow land and roadside and from fodder tree is also available in the peri urban areas.

Types of farms in Nepal

1.   Smallholders (58%)
2.   Commercial (29%)
3.   Multilocation (9%)
4.   Research (3%)
5.   Others (1%)

Breeding system

Breeding system of buffalo is unplanned due to which the blood level of indigenous buffalo is progressively eroded. Breeding with available bulls, breeding of buffalo without breed registration and force killing of male calves causes negative selection and decreases breed purity. Nowadays breeding with exotic bulls (Murrah) for milk production is common among farmers. Conceptionrate of AI for buffalo (35%) is lower than the cattle; so natural mating is common in buffalo.
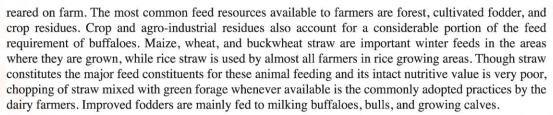
Use of male calves

Male buffalo calves are mainly used for the meat propose as buffalo meat is cheap source of animal protein and buffalo meat contributes about 36.13% of total meat production. About 16% of male calves are selected for breeding and 23% calves for drought purpose. In context of our country, male calves are also used for religious purpose; for instance, in Gadhimai mela, thousands of male buffalo calves are sacrificed.

Feeding system of buffaloes

The feeding system and the use of feed resources in the farming system prevalent among the buffalo farmers in Nepal is influenced by the cropping system, agro-ecological conditions, and the type of animal

reared on farm. The most common feed resources available to farmers are forest, cultivated fodder, and crop residues. Crop and agro-industrial residues also account for a considerable portion of the feed requirement of buffaloes. Maize, wheat, and buckwheat straw are important winter feeds in the areas where they are grown, while rice straw is used by almost all farmers in rice growing areas. Though straw constitutes the major feed constituents for these animal feeding and its intact nutritive value is very poor, chopping of straw mixed with green forage whenever available is the commonly adopted practices by the dairy farmers. Improved fodders are mainly fed to milking buffaloes, bulls, and growing calves.

Fodder tree plantation for feeding animals during the dry winter period is a common practice across hills of Nepal. Tree fodders are cut and carried to households for feeding dairy buffaloes. They are important source of green feed for dairy animals during that period. In subsistence dairy animal production system, foliage collection from nearby forest (government or community forest) is also very common. Recently open land under community forestry has been extensively utilized for fodder production in the milk pocket areas of the country. Excess grass is cut and made into hay for winter feeding in these areas. Similarly, commercial concentrate feed mixtures are mostly supplied by the private feed manufacturing plant with most of the ingredients being imported from India. Concentrate feed is generally unaffordable for most traditional and transitional farmers. Other farmers feed their animals with concentrate mixture consisting of rice bran, mustard oil cake, molasses, and salt.

Housing system

Most of the farm has conventional housing system with some having loose system. Good husbandry practices is followed in most of the buffalo farming.

Buffalo health care status

Animal health plays an important role in animal production. In turn, animal health is influenced by factors such as disease resistance, nutrition, and the animals' environment. Parasite infestation is a major economic disease as it affects milk production to a considerable extent, where intestinal worm infestations and external parasites are the major problems in buffaloes. In Nepal, though sporadic information is available, comprehensive analysis of the economic loss due to these diseases and parasites in the country is still lacking. Rinderpest disease, which used to be the main cause for economic losses, has been eradicated from the country. Nowadays, Hemorrhagic Septicemia (HS), Foot and Mouth Disease (FMD), mastitis, infertility, metabolic diseases and internal parasites are some of the economically important diseases prevalent in buffaloes.

Source of veterinary services

Government provides veterinary extension services to farmers through various level of livestock service centres which provides essential veterinary services, animal health care and management advice to farmers. Private sectors such as private veterinarian offers veterinary services, treatment and prevention of diseases and agrovets offers farm inputs such as medicine, feed supplements and feed to farmers. Local level lower technicians such as Village Animal Health Workers (VAHW) are trained on providing basic

veterinary services, vaccination and awareness to local farmers. However, there are inadequate technician level manpower and those who are available also do not have good skill and knowledge.

Buffalo and buffalo marketing system

Dairy Sector in Nepal

Annual milk production in Nepal is 2,566,614 MT and per capita milk availability is 89 liters per year (MoALD, 2023). Of the total milk produced in the country, 65% is consumed at household level while only 35% is marketed through informal (20%) and formal (15%) sectors. As dairy sector contributes 9% to Nepal's Agriculture Gross Domestic Product (AGDP), it is vital not only to family nutrition and household economy but also to national economy, with direct cash transfer from urban consumers to rural producers through milk business. Nepali dairy industry depends mostly on smallholder milk producers who produce a few litres of milk daily, and numerous small processors who collect and process a few hundred litres of milk targeting local markets. Except four or five large dairies that process more than 100,000 litres of milk daily, about 2,000 plus milk processors and 1,600 plus milk cooperatives spread across the country play important role in marketing of milk and milk products in Nepal.

Milk production seasonality

Milk production is influenced by various factors such as seasonality, environment, biological and managemental factor. In Nepal, strong seasonal variation in milk production and demand exists,
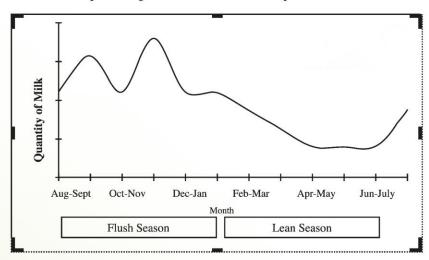
Figure 6: Seasonal variation in milk production in Nepal.

with production decreasing in summer (lean season) while experiencing glut during winter (flush season) (Figure 6). In context of our country Milk production is peak during post rainy season i.e autumn season from September to November due to availability of green lush fodder and moderate temperature. Milk production gradually decreases in winter season due to cold and harsh environment. In winter season availability of green fodder also decreases leading to dependent on dry hay which results is decrease in milk production. In summer season i.e from April to July there occurs sharp decrease in milk production due to heat stress which leads to decrease in feed intake which ultimately results in decrease in milk yield.

Milk product diversification

From milk, various dairy products are produced some of the popular dairy products are ghee, paneer, and cheese which have high market value and long self-life. Other products like yogurts, sweets such as Gulab jamun, Lal Mohan, ice-cream etc. are commonly produced from milk which are popular dessert in the country.

Milk value chain

The key actors in the formal dairy value system include milk producer farmers, Milk Producers' Co-operatives Societies (MPCS), Milk Collection Centers (MCC), milk processing plants/factories, milk selling booths and institutional buyers. Firstly, there are rural farmers and their function is to be engaged in milk production (FAO, 2010). The next are MPCSs established in the rural areas. Farmers, from the surrounding villages, carry their milk production to the nearest MPCS where their milk is received, measured, recorded and samples are taken for quality check mostly on the basis of fat and solids-not-fat (SNF). After receiving milk from all farmers, it is then transported to the nearest MCC. Some of the MPCSs have their own chilling system where they chill the milk, deliver it to the DDC and/or private MCCs or sell in the local market.

Next are the MCCs where milk received from the MPCSs is measured, recorded, and platform quality control tests and occasional adulteration test are performed. Milk in the MCC is cooled by either instant chilling system or in the bulk milk cooling vat. Some MPCSs process the milk to produce packaged milk, butter and other dairy products such as paneer, yoghurt (dahi) and milk solids (Khuwa). Milk from other MCCs is transported to the milk processing plants in insulated bulk milk tankers (FAO, 2010). The milk processing plants firstly perform quality control tests and quality passed milk is then measured and cooled prior to keeping it in an insulated milk storage tank for further processing and producing pasteurized milk and milk products. After processing, milk and milk products are kept in cold store for sales.

The last actors are the milk selling booths/dairy shops and institutional buyers. The milk booths sell only milk to the consumers/tea shops, and dairy shops mostly sell milk products to the consumers. The institutional buyers include hotels, supermarkets/departmental stores and fresh houses. Among these, hotels use milk and milk products for their own purposes whereas supermarkets/ departmental stores and fresh houses sell milk products to the consumers.

Milk also passes through the informal channel where individual farmers or the contractors are the main actors who directly deliver milk to the individual households/tea shops/sweet shops etc (FAO, 2010).

In short, rural farm families keeping a few low productive dairy animals are the main producers. These milk producer farmers are organized in milk producers' cooperatives. Many cooperative collect and process milk and sell milk products locally. The cooperatives sell surplus milk to larger dairies which are very few and far between. The government owned Dairy Development Corporation (DDC) is the larger player in milk market. A national milk grid is established connecting major production areas (Eastern and Central Nepal and terai districts) with big consumer markets. Price of milk and milk products is set by DDC; and strong seasonal variation in milk production and demand exist, with production decreasing in summer (lean season) while experiencing glut during winter (flush season).

Meat value chain

The meat value chain is not as distinct as that for the milk value chain in buffaloes. Nonetheless, the key actors in the formal meat value system include producer farmers, individual animal collector or the middlemen, slaughter plants/factories, and processing units and butchers/retail shops. The meat animals are mostly the males and the unproductive or dry female buffaloes. And, in some parts of the country, farmers produce the fattened calves for the slaughter purpose. The animal collectors go to the villages and household to purchase and collect the animals. Usually, local markets and "haat bazzars" are places where the trading for the animals takes place between the different stages of middlemen. They transport the animals to the slaughtering plants/factories where the humane slaughtering takes place where they try to adhere to the regulations to ensure the meat quality. Afterwards, the butchers in the retail shops break down the carcass into various cuts, which is sold as fresh meat or further processed. The processing and packaging units produce different forms like minced meat, sausages, or marinated cuts. The retail market is constituted by the supermarkets, hotels and food service. The cold chain is managed for the transportation to these places and for storing the meat and processed items for longer periods.

By-products like hides, bones, and offal can be used in other industries to produce multiple products. Such

as leather production and processing units make hides/skins into shoes, belts, bags and other items. The hooves, horns and hairs are processed to make crafts and tools, brushes and fertilizers. The bone meal, blood meals are utilized by feed mills in animal and pet feed. The tallow and fat are also processed to produce cooking oils, and soap and candles.

Constraints of buffalo development in Nepal

The challenge is how to design an efficient breeding program using low productive stock under local conditions where resources are limited and feed availability varies in harsh environments (Gunawardena, 2008). Low productivity of the indigenous buffaloes due to low genetic potential, seasonality of reproduction, slow adoption of artificial insemination, lack of breeding bulls, shortage of technical manpower for buffalo husbandry, lack of public awareness about buffalo husbandry, poor attention in buffalo research and development, and scarcity of feeds and fodder.

These genetic resources are progressively being eroded mainly due to unplanned breeding as a result of the radical shift of livestock development to commercial farming systems and also due to lack of policy. There is almost unrestricted interbreeding among different breeds and there is a marked decline in the availability of unique animals conforming to the attributes of defined breeds, particularly in their native breeding tracts. The situation is further complicated by the fact that there exists no breed societies or breed registration/ improvement societies to register animals of specific breeds, maintain herd books and ensure the purity of the breeds. The germplasm of such well-defined breeds constitutes a valuable genetic resource which needs to be conserved on priority basis. Hence, the need to curb the threats of dilution and extinction of the valuable buffalo genetic resources, by strategic development and conservation, has never been more justifiable for sustainable utilization.

Future improvement plan or trend

Although buffalo plays a principal role in the national economy, it had never been addressed properly rather always neglected in Nepal. Nevertheless, in the recent decade, the Nepal government significantly intensified efforts to boost buffalo productivity through various initiatives managed by Department of Livestock Services and Nepal Agricultural Research Council. These initiatives encompass a broad range of programs such as genetic improvement of buffaloes, genetic selection, community-level distribution of buffalo bulls, artificial insemination, forage development, conservation strategies, specialized nutrition programs for newly calved buffaloes, and male buffalo fattening for meat production across numerous regions of the country (Nirmal, 2018; Gorkhali, 2021, Siddiky, 2015). Furthermore, long term breeding strategies with special references to present and future farming system should be focused (Chantalakhana and Skunmun 1999). To accelerate the growth and development of Buffaloes, it is necessary to promote the following activities:

Genetic improvement of indigenous buffaloes by crossbreeding and grading up

In order to increase the production of buffaloes in National level, Murrah was introduced from India for upgrading indigenous buffaloes and that has led to crossbred buffalo population in the major dairy pocket areas of the country. After a restriction of genetic material exchange from India, Murrah population of Nepal has started to suffer from inbreeding due to lack of preparation for maintenance of the Murrah buffalo breeding stock. In order to become self-dependent on availability of high genetic merit Murrah bull mothers, the Department of Livestock Services (DLS) and Nepal Agricultural Research Council (NARC) have jointly initiated the Buffalo Genetic Improvement Project (BGIP) and is being implemented in 10 districts along with two government buffalo farms (one from DLS and one from NARC) since mid of 2010. Programs such as registration of high yielder buffaloes, identification of bull mothers implementing Pedigree Performance Recording Scheme (PPRS), production of genetically superior bull and progeny testing program was launched for their extensive utilization through Artificial Insemination (AI). Further projects on genetic improvement are continued as NLSIP project funded by World Bank since 2018 and as a activity of SAPLING project of ILRI: African Asian Dairy Genetic Gain (AADGG) since 2022. Presently, rare examples are available for the development or selection of superior sires for breeding buffalo population. It is, therefore, essential to continue a project more effectively to identify bull mothers for the production of progeny tested bulls for covering larger number of buffalo population.

Recently in 2023, high genetic merit Murrah buffalo bulls were bought from India which used for semen collection and distribute throughout the country expecting the country's dairy and meat development.

Genetic improvement of well-defined indigenous buffaloes by selective breeding

Nepal has four different indigenous buffalo breeds as described earlier are characterized in phenotypic level, chromosomal level and also in genotypic level (production and molecular level). The principal hindrances in genetic improvement in buffalo population is infertility. The research has proven that high infertility exhibited was not due to chromosomal aberration or difference in chromosomal numbers as all available buffalo breeds including wild buffalo are riverine type (Amatya et al., 2000) and is mainly due to nutritional deficiencies and imbalances causing delayed maturity, infertility and abortions in females and reduced libido and decreased sperms concentration and motility in males (Joshi et al, 2000). Furthermore, the principal questions related to buffalo female such as late age at first calving, the high incidence of postpartum anestrus and high silent heat experienced in buffaloes has been addressed to some extent. Nonetheless, the conception rate on AI is uniformly lower in buffaloes than in cattle, thus reducing the speed of progress might be due to silent heat. Heat synchronization using hormone, however, was developed which is effective in buffalo. Furthermore, Fixed Time Artificial Insemination (FTAI) is recently introduced and is in the process of verification. Freezing and storage of buffalo semen has been studied (Devkota, Sah and Gautam, 2023).

In case of Indigenous buffalo breeds, selective breeding for genetic improvement of native breed in some potential pockets have been recommended owing to the variability in the performance of indigenous buffaloes. High merit indigenous buffaloes (Lime and Parkote) are kept at Directorate of Agricultural Research, Gandaki Province, Lumle as buffalo bull mother farm for indigenous buffaloes. Nevertheless, the improvement of the indigenous buffalo could only be possible through organizing buffalo producers to form breeding societies, sound AI service, and maintenance of proper record and selection of superior sires. Clear breeding strategy for buffalo commodity is lacking for indigenous breeds as well as exotic breeds which is urgently recommended for the improvement of the productivity of buffalo commodity. Recently, Nepal has got National Livestock Breeding Strategy, 2022 which envisaged the conservation and improvement of buffalo breeds of Nepal through selective breeding for indigenous buffaloes whereas crossbreeding for the non-descript populations. Various researches have shown the genetic potential of the indigenous buffalo (Amatya et al, 2000) to support this policy. Breeding programs and optimal utilization require knowledge of genetic variability that is diversity within and among breeds and populations. Therefore, data on magnitude of genetic differentiation and genetic relationships among breeds and populations are warranted for defining the best approaches to the conservation of genetic resources. Since generating database is challenging and costly, a study on association of microsatellite with milk production in buffalo (Gorkhali et al., 2024) which as shown the positive indication.

We cannot neglect the fact that average milk production of buffaloes in the country is comparatively lower than their inherited potentiality. Various studies on the productivity of indigenous buffaloes revealed that more than 1000 lit of milk in a standard lactation period could be produced if proper management and husbandry practices was applied (Amatya et al., 2000; Shrestha et al., 2013) with wide variation of milk production potential ranging from 300 to 2300 liters per standard lactation period of 305 days (Shrestha et al., 2013). Despite having no influence of any critical selection, the performance of indigenous buffalo in terms of milk and meat production and reproductive parameters is very close to that of the exotic stock introduced in Nepalese environment (Amatya et al., 2000; Shrestha et al., 2013). Considering the existing variation in milk production and genetic potential of indigenous stock, an effective measure needs to be taken for improving the productivity of buffalo through selective breeding program.

Advanced technologies for genetic improvement

There is considerable interest in the application of advanced molecular and genetic technologies to identify those associated with various productivity traits. It promotes more efficient and relatively easy selection and breeding of farm animals with an advantage for inheritable characteristics of meat and milk

productivity. A number of molecular tools have been used to study the level and distribution of molecular diversity in water buffalo populations from various countries including microsatellite markers, restriction fragment length polymorphism (RFLP), simple sequence repeats (SSR), random amplified polymorphic DNA (RAPD), single nucleotide polymorphism (SNP), and whole genome. These tools are valuable and provide a comprehensive view of the molecular variations in the genome of the animal. Recently, the whole genome-based technology has been crucial and extensively applied in the areas of animal production practices, animal health and welfare, and evolutionary studies (Lenstra et al, 2012). The technological advances in the field of genomics with its wide range of applications has opened avenues to its potential current and future applications in animal genomic research (Pareek et al, 2011; Khan et al, 2022). Moreover, the recent developments in cost-effective and rapid sequencing technologies have instigated the exploration and understanding of global animal genomic resources including the buffaloes (Olschewsky et al, 2021).

Based on the genetic insights provided by these technologies on the Nepalese buffaloes, programs could be developed to prioritize their genetic diversity and adaptability through tailored conservation and breeding strategies. These programs could utilize techniques like genomic selection to improve economically important traits while maintaining breed integrity and adaptability. Disseminating this knowledge about genetic resources could foster community-led conservation and breeding efforts in buffaloes in Nepal. Additionally, these findings can be used to inform policy-makers at the national level to draft and implement policies focused on the sustainable development of buffalo breeds in Nepal. This can include support for conservation initiatives, promotion of sustainable breeding programs, and enhancement of the economic viability of buffalo farming in Nepal.

Recommendations on thematic strategies based on National Livestock Breeding Policy for development of buffalo

(1) Selective breeding of indigenous breeds in the breeding tract

- Production of high genetic merit (HGM) disease free bulls
  - o Field performance recording program
  - o Pedigree selection program (PS)
  - o Progeny testing program (PTP)
  - o Bull mother farm (Public Private Partnership) in their respective home tract
  - o Assisted Reproductive Technology (ART)
- * ET
- * MOET
  - o High genetic merit (HGM) disease free bulls for semen production
  - o Increase AI coverage
  - o Genomic selection

(2) Maintaining the purity of exotic breed (Murrah or any other suitable breeds)

- Exchange of germplasm (live animals, semen and embryos)
- Increase variation in the population
- Concept of Nucleus herd, Multiplier herd, beneficiary herd (crossbreds) formation
- Production of high genetic merit (HGM) disease free bulls
  - o Field performance recording program
  - o Pedigree selection program
  - o Progeny selection program
- Multi-location Bull mother farm (Public Private Partnership)
- Assisted Reproductive Technology (ART)
  - o ET
  - o MOET
- High genetic merit (HGM) disease free bulls for semen production
- Increase AI coverage

(3) Grading up of non-descript population
- High genetic merit (HGM) disease free bulls for semen production
- Increase AI coverage
- Bull production program (Bull produced through scientific breeding program)
- Semen production through high genetic merit (HGM) disease free bulls
  - o PTP
  - o PS
  - o ETT

(4) Crossbreeding of non-descript population
  - o Using imported semen (Murrah or other suitable breeds)
  - o Imported embryos
  - o Bulls

(5) Conservation of indigenous breeds
- in situ conservation
  - o Bull mother farm (farmers' level)
- ex situ conservation
  - o Cryopreservation
  - o Bull mother farm (on farm level)
- Using Advanced technology for genetic improvement
  - o Assisted Reproductive Technology (ART)
- * ET
- * MOET
  - o Molecular techniques (MAS)

(6) Emphasis on research and development on genetic improvement of buffalo

• National Buffalo Research Program (National level) and Satellite Research Centres (Specific regional level) in the home-tract and outreach centres (farmers' level)

Specific Regional Cooperation Area
- Investigation of genetic variations in buffalo and breed improvement (semen sourcing)
- Capacity Building (Short-term trainings, Reproductive biotechnology, semen processing, AI, exposure visits, workshops, seminars)
- Technologies and Innovations
  - o Value addition /niche products
  - o Fodder / forage management
  - o Fodder germplasm availing/exchange, nutrition blocks

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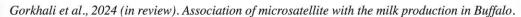
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Buffaloes in Pakistan: keystone of agricultural economy and pathway to sustainable growth

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Abstract

The livestock sector has emerged as the largest contributor to agriculture, accounting for approximately 60.84 percent of the agriculture value added and 14.63 percent of the national GDP during the year 2024. Animal husbandry is a critical economic activity for rural dwellers in Pakistan, with over 8 million rural families engaged in livestock production and driving 35 to 40 percent of their income from this sector. Buffaloes in Pakistan significantly contribute to the national economy by providing milk, meat, hides, and draught power. Buffaloes also form a major capital reserve of farming households, provide security, and generate cash incomes for rural populations. Accounting for approximately 60% of the country's total milk production, the high-fat content of buffalo milk makes it ideal for traditional dairy products. The buffalo population has driven up from 20 million in the early 1990s to more than 46.3 million by 2024, with the majority distributed in Punjab and Sindh provinces. Buffalo farming practices have progressed from conventional extensive approaches to more profitable semi-intensive and intensive systems. Simultaneously, the productivity and welfare of buffalo have increased through developments in nutrition and healthcare driven by initiatives from the public and commercial sectors. Breeding programs, emphasizing artificial insemination and genetic enhancement, aim to meet the rising demand for buffalo products. Furthermore, the marketing strategies are focused on both domestic consumption and export opportunities, particularly to the Middle East, China, and Southeast Asia. As a way forward, public-private collaborations are crucial for future advancements, utilizing resources and expertise to advance breeding, health management, and market access. For the long-term growth of the buffalo industry, the implementation of sustainable practices and climate resilience will provide Pakistani farmers with better economic opportunities and means of livelihood.

Keywords: Milk and meat production, nutrition, genetic enhancement, export opportunities, sustainable practices, climate resilience.

Introduction

Buffaloes are at the heart of Pakistan's rural landscape, weaving a rich tapestry of cultural and economic significance. These resilient animals are more than just livestock; they are lifelines for millions of rural families. Their contribution to the agricultural economy is profound, providing amajor source of milk and meat, essential for both domestic consumption and export markets. Buffalo milk, renowned for its high-fat content and rich flavor, is a staple in traditional dairy products like yogurt, butter, and ghee, forming a significant part of the Pakistani diet. Over the past three decades, the journey of buffalo farming is not without its challenges. Government and private sector initiatives have played pivotal roles in advancing buffalo nutrition, healthcare, and breeding programs. Looking forward, public-private partnerships and sustainable practices will be crucial in navigating future challenges and capitalizing on emerging opportunities, ensuring buffalo farming remains a cornerstone of Pakistan's agricultural economy.

a) Importance of Buffalo in the Agriculture and Livestock Sector and National Economy of Pakistan

In Pakistan, buffaloes are credibly the spine of livestock, which directly impacts the agriculture landscape and national economy. They are the lifeline of the rural economy providing a critical supplementary source of employment and income to millions of rural families and households. They are a major source of milk in the dairy industry which accounts for about 60 percent of total milk production in the country. Buffalo milk has a high fat content, and hence milk yield is greater, which makes it ideal for traditional

dairy products such as yogurt, butter, ghee, and cheese. The adaptability and robustness of buffaloes to the varied climatic conditions of Pakistan further accentuate their role in maintaining the small-scale farmers' livelihoods and assuring food security in the region.

Livestock is a crucial subsector of Pakistan's agriculture, contributing approximately 60.84% of the agriculture and 14.63% to the gross domestic product (GDP) has grown at 3.89% in the year 2023-24, with buffaloes playing a major part in this contribution. Buffalo milk and meat production, as well as their byproducts, contribute significantly to the agricultural economy. The export of buffalo meat has increased, with Middle Eastern countries being significant importers, boosting foreign exchange revenues. Government measures to promote buffalo productivity through breeding, nutrition, and healthcare services have increased the economic impact of buffalo.

Buffaloes have multiple use apart from the milk produced in the agricultural sector. This makes them crucial in areas, for drought where mechanized farming is an economic impossibility. They are used for agricultural purposes such as plowing, goods transportation, and producers of organic fertilizer used in farming, as well as for leather and hide production. The incorporation of buffaloes in farming systems increases agricultural productivity and sustainability. Moreover, multiple cottage industries are based on by-products of buffalo farming such as hides and bones, contributing to rural development and poverty alleviation. The fact that buffaloes are utilized in multiple farming activities is an important feature as it highlights the importance of buffalo in supporting the socio-economic foundation of rural communities in Pakistan.

Furthermore, buffaloes are integral to the cultural and social fabric of Pakistan. They are often regarded as a symbol of wealth and social status in rural areas. Festivals and fairs featuring buffaloes, such as livestock shows and bull races, are popular and highlight the deep-rooted cultural significance of these animals. Additionally, buffaloes contribute to gender empowerment in rural areas. Women, who are primarily responsible for milking and managing dairy buffaloes, benefit economically and socially. This empowerment through livestock management not only enhances household income but also improves women's status within their communities. The social and cultural importance of buffaloes, therefore, extends beyond their economic contributions, reinforcing their value in Pakistan's rural and agricultural landscape.

b) Buffalo Population, Buffalo Milk and Meat Statistics and Distribution

The country is home to five primary buffalo breeds: Nili, Ravi, Nili-Ravi, Kundi, and Aza Kheli. The Nili, Ravi, and Nili-Ravi are predominantly found in Punjab and are known for their high milk production. Kundi, common in Sindh, is valued for its adaptability and resilience. Whereas, Aza Kheli is a native of Khyber Pakhtunkhwa (KP). Over the previous three decades, Pakistan's buffalo population has grown significantly. According to data from the Food and Agriculture Organisation (FAO) and the Pakistan Bureau of Statistics (PBS), the buffalo population has grown from approximately 20 million in the early 1990s to more than 46.3 million by 2024. This expansion can be credited to increased demand for buffalo milk and meat, improved breeding practices, and better veterinary care.

Climate, water availability, and farming techniques all have an impact on the geographical distribution of buffaloes in Pakistan. Punjab has the greatest buffalo population owing to its massive canal irrigation system and fertile soil. Further, a strong dairy infrastructure and market access contribute to its dominance in buffalo farming. Sindh, notably the areas surrounding Karachi and Hyderabad, has a sizable buffalo population, which benefits from its proximity to large urban centers. In contrast, the buffalo population in KP and Balochistan is very small, and it is integrated into mixed farming systems that support local livelihoods.

The movement of dairy buffaloes within Pakistan is a significant aspect of management and trade, driven by regional demand. Nili-Ravi buffaloes, renowned for their high milk production, are frequently moved to Sindh and Balochistan to meet the increasing dairy needs and capitalize on market opportunities. Similarly, Kundi from Sindh are transported to Balochistan, where they contribute to local milk

production and enhance the genetic pool. Additionally, the movement of culled buffaloes for meat is a common practice, with Punjab serving as a major supplier. These are transported to KP, Gilgit-Baltistan GB, and Kashmir, where they are in high demand for meat consumption. This interprovincial trade not only supports the livelihoods of farmers and traders but also ensures a steady supply of dairy and meat products across Pakistan.
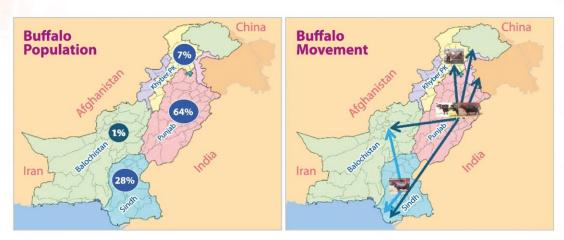

Figure 1: Geographical distribution of buffalo population by province and movement of dairy buffalo among provinces of Pakistan.

Buffalo milk output has also grown significantly over the last 30 years. In the early 1990s, buffaloes produced roughly 16 million tonnes of milk per year. This quantity has more than doubled, with current projections estimating an annual output of more than 41 million tonnes. Buffalo milk is considered a premium product in Pakistan due to its high-fat content and rich flavor, making it a popular choice for dairy products including yogurt, butter, and ghee. The Punjab province leads in milk production, accounting for more than 70% of total buffalo milk output, followed by Sindh.
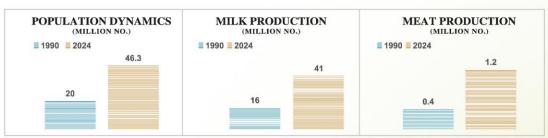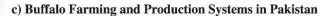
Figure 2: Buffalo population dynamics, milk, and meat production increase in last 30 years in Pakistan.

areas. Women, who are primarily responsible for milking and managing dairy buffaloes, benefit economically and socially. This empowerment through livestock management not only enhances household income but also improves women's status within their communities. The social and cultural importance of buffaloes, therefore, extends beyond their economic contributions, reinforcing their value in Pakistan's rural and agricultural landscape.Meat production from buffaloes has also witnessed considerable growth. In the early 1990s, buffalo meat production averaged over 400,000 tonnes per year. In recent years, this figure has risen to almost 1.2 million tonnes. The increase in meat output is supported by rising domestic and worldwide demand for buffalo meat, which is noted for its lean quality and rich flavor. The export market for buffalo meat has grown, with large shipments to the Middle East and Southeast Asia.

c) Buffalo Farming and Production Systems in Pakistan

The evolution of buffalo farming systems in Pakistan reflects the dynamic nature of agricultural practices and the need to adapt to changing economic, environmental, and social conditions. Historically, buffalo farming was predominantly extensive, relying on natural grazing and traditional methods. More structured systems, such as transhumant, semi-intensive, and intense commercial farming, have evolved throughout time to increase production and fulfill the expanding demand for buffalo products.

Table 1: Buffalo farming and production systems in Pakistan with estimated number of heads and population in each system.

Production Systems	Buffalo heads in each System (Animal No.)	Buffalo population in each system (Million No.)
Extensive	1-6	24.40
Transhumant	7-15	13.24
Semi-intensive	16-50	5.42
Intensive	> 50	3.24
Total		**46.30**

Traditionally, extensive buffalo farming involved grazing buffaloes on natural pastures, communal lands, and agricultural by-products. Farmers relied heavily on the seasonal availability of fodder and water, with minimal inputs for feeding and healthcare. It is particularly common in rural areas where buffaloes roam freely and feed on whatever vegetation is available. The challenges included vulnerability to environmental changes, seasonal fluctuations in fodder supply, and limited access to veterinary services.

Transhumant farming, a more organized approach, involves the seasonal movement of buffaloes between different grazing areas. This system is still practiced in some parts of Pakistan, particularly in the northern regions where buffaloes are moved to high-altitude pastures during the summer and brought back to lower areas in the winter. It allows for the optimal use of available grazing resources throughout the year, mitigating some of the limitations of extensive farming. Despite its benefits, transhumant farming is gradually declining due to changing land use patterns and increasing pressure on grazing lands.

The shift towards semi-intensive farming represents a significant development in buffalo farming practices in Pakistan. In this system, buffaloes are kept in enclosed areas or paddocks and are provided with supplementary feeding in addition to natural grazing. Semi-intensive farming combines the advantages of controlled feeding with the benefits of natural grazing, leading to improved milk and meat yields. This system is particularly prevalent in peri-urban areas, where farmers have better access to markets, veterinary services, and feed resources. Semi-intensive farming allows for more efficient use of land and resources, reduces the risk of overgrazing, and enhances disease management. However, it requires higher investments in infrastructure, feed, and healthcare.

Intensive commercial farming, the most modern and productive system, involves raising buffaloes in confined spaces with high levels of management and input. This system is characterized by controlled feeding regimes, regular veterinary care, and advanced breeding practices. Intensive farming is predominantly found near urban centers where there is a high demand for buffalo milk and meat. It allows for maximum productivity and efficiency, with buffaloes producing higher quantities of milk and meat compared to extensive or semi-intensive systems. The challenges of intensive farming include high operational costs, the need for skilled labor, and the management of waste and environmental impacts. Nevertheless, intensive commercial farming is seen as the future of buffalo farming in Pakistan, driven by the need to meet the growing market demands and improve the livelihoods of farmers.

d) Nutrition and Health Care Service for the Buffalo

Over the years, significant advancements have been made in understanding and improving the nutritional

requirements and healthcare services for buffaloes in Pakistan. These advancements are critical for increasing milk and meat production, guaranteeing animal welfare, and sustaining the livelihood of farmers.

Nutrition

The nutritional management of buffaloes in Pakistan has transitioned from traditional feeding practices to more scientific and balanced approaches. Traditionally, buffaloes were fed on agricultural residues, natural pastures, and fodder crops such as berseem (Egyptian clover) and maize. While these feeds provided basic nutrition, they often lacked the necessary balance of nutrients required for optimal production. Today, there is a greater emphasis on providing balanced The incorporation of feed supplements such as urea-molasses blocks, mineral mixtures, and vitamin premixes has further enhanced the nutritional status of buffaloes. These supplements address common deficiencies and improve overall health and productivity. Silage and haymaking have also gained popularity as methods to preserve high-quality forage for the dry season, ensuring a consistent supply of nutritious feed throughout the year.

Healthcare Services

Healthcare for buffaloes in Pakistan has seen considerable improvements, driven by both government and private sector initiatives. Veterinary services are more accessible than in the past, with a network of veterinary hospitals, dispensaries, and mobile clinics providing essential health services. Routine health management practices such as vaccination, deworming, and regular health check-ups are increasingly adopted by farmers. Vaccination programs target major diseases like foot-and-mouth disease (FMD), hemorrhagic septicemia, and black quarter, which are prevalent in buffalo populations. Regular deworming programs have aided in the control of internal and external parasites, as well as the efficiency with which feed is converted. Additionally, the government has established disease surveillance and diagnostic centers to monitor and manage animal health issues more effectively. These centers play a vital role in early detection and control of diseases, minimizing the risk of large-scale outbreaks.

Challenges and Future Directions

Despite considerable improvements, buffaloes in Pakistan face ongoing nutritional and healthcare challenges, especially in traditional farming systems. To address these issues, it is crucial to educate farmers on modern feeding and healthcare practices, strengthen veterinary services, and expand mobile vet units. Public-private partnerships and continuous research in buffalo nutrition and health can also help improve their overall well-being and productivity.

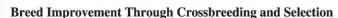## e) Buffalo Breeding and Improvement System in the Country

Buffalo breeding and improvement systems in Pakistan have undergone significant evolution, aimed at enhancing productivity, genetic potential, and overall herd quality. Historically, buffalo breeding was largely based on traditional methods. Farmers relied on natural mating within their herds, with little emphasis on selective breeding. This inbreeding led to a slower rate of genetic improvement. As a result, the genetic potential of buffaloes was not fully harnessed, leading to suboptimal productivity in terms of both milk and meat yields. The deriving force to focus on improving buffalo breeds is the need to meet increasing demands for milk and meat, as well as to improve the livelihoods of smallholder farmers.

Government Initiatives and Breeding Programs

Recognizing the limitations, Pakistan government has initiated several programs to enhance buffalo breeding. The establishment of the Buffalo Research Institute at Pattoki and the Punjab Buffalo Breeders Association has been pivotal in implementing structured breeding programs. The initiatives include the registration and data recording of buffaloes both at Government and private breeding farms, progeny testing programs, and artificial insemination services has gained popularity as a method to introduce superior genetics into the buffalo population.

Breed Improvement Through Crossbreeding and Selection

Crossbreeding and selection are key components of buffalo improvement strategies in Pakistan. Crossbreeding programs aim to combine the desirable traits of these breeds to produce offspring rations that include energy, protein, minerals, and vitamins. The use of formulated concentrates and commercial feeds has increased, particularly among semi-intensive and intensive farming systems. These feeds are designed to meet the specific dietary needs of buffaloes at different stages of their life cycle, from growth and lactation to reproduction and maintenance. with enhanced performance characteristics. Performance recording and genetic evaluation systems are gradually being adopted to support these efforts, enabling more accurate and efficient selection of breeding stock.

Challenges and Future Directions

Despite the progress, several challenges hinder the effectiveness of buffalo breeding and improvement systems in Pakistan. One major challenge is the limited availability of trained personnel and technical expertise in modern breeding techniques like embryo tranfer technolgy. Additionally, the adoption of AI and other advanced breeding methods is constrained by logistical issues and inadequate infrastructure in remote areas. Farmer awareness and education also play a critical role in the success of breeding programs. Efforts to increase farmer participation in structured breeding programs are essential, as is the provision of incentives to adopt best practices. The future of buffalo breeding in Pakistan lies in the integration of biotechnology, such as genomic selection and embryo transfer, which can accelerate genetic improvement. Strengthening collaboration between research institutions, government agencies, and the private sector will be crucial in addressing these challenges and advancing buffalo breeding initiatives.

f) Marketing of Buffalo and Buffalo Products

The marketing of buffalo and buffalo products, primarily milk and meat, are highly valued for their quality and nutritional benefits. The marketing system for these products has evolved significantly over the years, driven by both domestic demand and export opportunities.

Domestic Market Dynamics

The domestic market for buffalo milk and meat is substantial, with buffalo milk accounting for more than 60% of the total milk produced in Pakistan. Buffalo milk is preferred over cow milk due to its higher fat content and richer taste, making it ideal for producing traditional dairy products such as ghee, butter, yogurt, and various sweets. Marketing of buffalo milk typically involves several intermediaries, including local milk collectors, wholesalers, and retailers, who facilitate the movement of milk from rural production areas to urban markets. The informal sector dominates the milk market, with a significant proportion of milk being sold unpasteurized and directly to consumers or local dairies. This informal market is characterized by its flexibility and lower transaction costs, but it also faces challenges such as quality control, adulteration, and lack of standardization.

The meat market for buffaloes is also significant, with buffalo meat (locally known as "beef") being a major source of animal protein for the population. The marketing channels for buffalo meat involve slaughterhouses, meat processors, wholesalers, and retailers. Urban centers such as Karachi, Lahore, and Islamabad are major consumption hubs, with a high demand for fresh meat. The domestic meat market is supported by a network of abattoirs and meat processing facilities, which ensure a steady supply of meat to retailers and consumers. However, issues such as inadequate cold chain infrastructure, lack of modern slaughtering facilities, and poor hygiene practices in traditional markets pose challenges to the efficient marketing of buffalo meat.

Export Market Potential

Pakistan has a growing export market for buffalo meat, particularly to countries in the Middle East, China, and Southeast Asia. Buffalo meat is valued in these regions for its quality and taste, and Pakistan's

geographic proximity to these markets provides a competitive advantage. The government has implemented policies to support meat exports, including the establishment of modern slaughterhouses that meet international standards, certification programs, and incentives for exporters. As a result, buffalo meat exports have seen a steady increase over the past decade. According to the Pakistan Bureau of Statistics, meat exports have grown significantly. However, to fully capitalize on the export market potential, Pakistan needs to address challenges such as compliance with international health and safety standards, improving traceability systems, and enhancing the overall quality of meat products.

Marketing Strategies and Future Directions

Effective marketing strategies are essential for maximizing the potential of buffalo products in both domestic and international markets. Branding and value addition, traceability are key areas where improvements can be made. For instance, developing strong brands for buffalo milk products and ensuring consistent quality can help capture a larger market share. Value addition through processing into products like cheese, butter, and packaged milk can also increase profitability for producers and processors. Additionally, marketing campaigns highlighting the nutritional benefits and unique qualities of buffalo milk and meat can boost consumer demand.

g) Future Buffalo Improvement Program of Private and Public Sector

The future of buffalo improvement programs in Pakistan hinges on synergistic efforts between the public and private sectors. Both sectors play critical roles in advancing buffalo productivity, genetic enhancement, and overall industry sustainability. As the demand for buffalo products continues to rise both domestically and internationally, coordinated efforts are essential to address existing challenges and harness new growth opportunities.

Public Sector Initiatives

The public sector in Pakistan has historically been a major driver of agricultural and livestock development. Moving forward, government-led initiatives will continue to be pivotal in shaping the future of buffalo improvement programs. The Ministry of National Food Security and Research (MNFSR) and various provincial livestock departments are spearheading efforts to enhance buffalo genetics, health, and productivity. Key initiatives include expanding artificial insemination (AI) services, establishing genetic improvement centers, and enhancing disease control measures. The government is also investing in the establishment of model dairy farms and training centers to disseminate best practices among farmers.

Moreover, the public sector is focusing on improving veterinary services and infrastructure. Efforts to modernize veterinary hospitals, establish mobile veterinary units, and implement robust disease surveillance systems are underway. These measures are essential for maintaining herd health and preventing disease outbreaks, which can severely impact productivity. Additionally, public research institutions and universities are conducting research on buffalo nutrition, reproduction, and genetics to develop innovative solutions for industry challenges. Public sector programs are also emphasizing capacity building through farmer education and extension services, ensuring that farmers are equipped with the knowledge and skills to adopt advanced farming practices.

Private Sector Contributions

Private companies, cooperatives, and non-governmental organizations (NGOs) are playing a crucial role in providing inputs, services, and market access to buffalo farmers. One of the key areas is the supply of high-quality feed and supplements. Private feed manufacturers are producing balanced rations and mineral mixtures that address nutritional deficiencies and enhance buffalo productivity. Furthermore, private veterinary service providers are offering specialized health care, including AI services, disease diagnostics, and treatment.

Private sector initiatives also extend to processing and marketing. Dairy companies are investing in modern processing facilities, cold chain infrastructure, and quality control systems to ensure that buffalo

milk and meat products meet consumer standards. These companies are also engaged in branding and marketing campaigns to promote buffalo products domestically and internationally. Additionally, private sector investments in research and development (R&D) are yielding new technologies and practices that improve buffalo farming efficiency. One significant recent endeavor in the buffalo sector is made by the Royal Group, China, with the aim of establishing corporate buffalo farming in Pakistan.
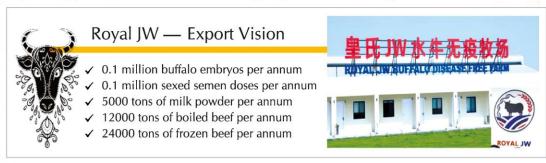

Royal JW — Export Vision

✓ 0.1 million buffalo embryos per annum
✓ 0.1 million sexed semen doses per annum
✓ 5000 tons of milk powder per annum
✓ 12000 tons of boiled beef per annum
✓ 24000 tons of frozen beef per annum

Figure 2: A private sector initiative and concept for disease free buffalo farming.

Public-Private Partnerships (PPPs)

Public-private partnerships (PPPs) are emerging as a strategic approach to buffalo improvement in Pakistan. These partnerships leverage the strengths of both sectors to achieve common goals. PPPs facilitate the sharing of resources, expertise, and technology, enhancing the overall impact of improvement programs. For example, collaborative projects between government agencies and private companies are advancing AI services by integrating state-of-the-art technologies and expanding coverage to remote areas. Similarly, joint ventures in the dairy sector are improving milk collection, processing, and distribution networks.

Furthermore, PPPs are instrumental in implementing large-scale breeding programs. By pooling resources, these partnerships can establish and maintain bull farms, semen production units, and progeny testing stations, ensuring a continuous supply of superior genetics. PPPs also support capacity building through joint training programs, workshops, and field demonstrations, fostering knowledge exchange and skill development among farmers and extension workers. These collaborative efforts are vital for scaling up successful practices and technologies across the buffalo farming community.

Future Directions and Challenges

Looking ahead, the future of buffalo improvement programs in Pakistan will depend on addressing several challenges and capitalizing on emerging opportunities. Key challenges include ensuring the sustainability of improvement programs, enhancing farmer participation, and maintaining genetic diversity. To overcome these challenges, continued investment in R&D, infrastructure, and human resources is essential. Embracing advanced technologies such as genomic selection, embryo transfer, and precision farming can accelerate genetic gains and improve productivity. Additionally, fostering a supportive policy environment that incentivizes innovation and sustainable practices will be critical.

Building resilience to climate change is another important aspect of future buffalo improvement programs. Climate-smart practices, such as developing heat-tolerant and disease-resistant buffalo breeds, will be crucial for adapting to changing environmental conditions. Furthermore, enhancing market access through better infrastructure, certification, and quality assurance systems can boost the competitiveness of buffalo products in domestic and international markets. Ultimately, the success of future buffalo improvement programs will hinge on the effective collaboration between the public and private sectors, driven by a shared commitment to advancing the buffalo industry and improving the livelihoods of farmers.

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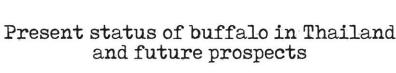
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Present status of buffalo in Thailand and future prospects

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Abstract

Buffaloes play a crucial role in Thailand's livestock sector, agricultural economy, and cultural heritage by providing draught power, meat, and milk, thereby supporting rural livelihoods and food security. Despite a decline in population from 5.5 million in the 1970s to 1.3 million in 2023 due to modernization and urbanization, recent initiatives and increased demand for buffalo meat have spurred a resurgence in farming. Currently, Thailand manages 1,784,160 buffaloes across 310,751 households. Buffalo farming systems have transitioned from traditional practices to semi-intensive and intensive approaches, integrating improved housing, nutrition, and healthcare. Nutrition and veterinary services are critical for productivity, with buffaloes primarily consuming fibrous plants supplemented during low-forage periods. Genetic improvement programs focus on enhancing Thai swamp buffaloes (*Bubalus bubalis carabanesis*) for growth, milk production, and disease resistance through genetic evaluation and advanced breeding techniques. Conservation efforts aim to maintain genetic diversity for sustainability. Buffalo products are vital to Thailand's agricultural economy; despite low daily milk production (2.0 ± 0.9 kg per cow), high butterfat content makes it valuable in niche markets. Buffalo meat, with dressing percentages of 53%-60%, is increasingly sought after. Live imports peaked at 23,332 heads in 2021, while exports reached 61,966 heads. Future improvements should address infrastructure, enhance market linkages, and leverage genetic advancements. Sustainable practices, supportive policies, and technological integration are crucial for resilience, preserving cultural heritage, and supporting rural economies in Thailand.
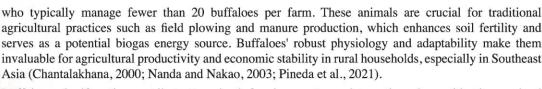
Keywords: Buffalo farming, genetic improvement, livestock sector, sustainability.

Introduction

Buffaloes have long been a cornerstone of Thailand's agricultural landscape, embodying significant cultural and economic value. Renowned for their resilience, buffaloes historically supported rice cultivation as primary draught animals. Beyond labor, buffaloes are pivotal in meat and milk production, vital for rural communities' nourishment and income. Despite their historical prominence, Thailand's buffalo population has declined due to modernization, mechanization, and shifts in agricultural practices. Urbanization and non-agricultural employment opportunities have further reduced buffalo rearing, raising sustainability concerns. Buffaloes support smallholder farmers, enhance food security, and bolster agricultural sustainability. This report examines the present state of Thailand's buffalo industry, including population trends, production statistics, and geographical distribution. It explores diverse farming systems, from traditional to modern practices, and emphasizes the importance of nutrition, healthcare, and genetic improvement programs. Additionally, the report discusses advancements in buffalo product marketing and the roles of cooperatives and farmer associations. Future prospects for buffalo farming are also assessed, focusing on initiatives aimed at industry rejuvenation through government policies and private investments.

1. Importance of Buffalo in the Livestock Sector, Agricultural Sector and National Economy
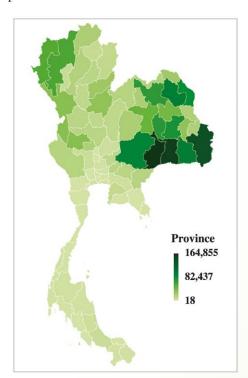
In Thailand, the buffalo plays a pivotal role in the livestock sector, particularly among small-scale farmers

who typically manage fewer than 20 buffaloes per farm. These animals are crucial for traditional agricultural practices such as field plowing and manure production, which enhances soil fertility and serves as a potential biogas energy source. Buffaloes' robust physiology and adaptability make them invaluable for agricultural productivity and economic stability in rural households, especially in Southeast Asia (Chantalakhana, 2000; Nanda and Nakao, 2003; Pineda et al., 2021).

Buffaloes significantly contribute to mixed farming systems, integrating rice cultivation, animal husbandry, and diversified crop production. Their role in plowing and organic fertilization promotes sustainable farming practices, reduces reliance on synthetic fertilizers, and enhances farm resilience (Tangtaweepipat et al., 2012). Buffalo farming also holds substantial economic significance, with products like meat, milk, and hides being highly valued in local markets. Increased demand for buffalo meat has spurred farming activities, supported by governmental and private sector initiatives, contributing to national food security and rural employment. Additionally, buffalo farming preserves cultural heritage and traditional practices, reflecting its broader socio-cultural importance (Indramongkol, 2005).

2. Buffalo Population, Milk and Meat Statistics and Distribution Over the Last 30 Years

As of 2023, Thailand's buffalo population stood at 1,784,160, managed by 310,751 farming households (Figure 1; Department of Livestock Development, 2023a). The Northeastern Region is the hub of buffalo farming, accounting for 72% of activities, followed by the Northern Region (20%), Central Region (6%), and Southern Region (2%). Buffalo milk production in Thailand is notably low compared to other countries. Thai swamp buffaloes (*Bubalus bubalis carabanesis*), primarily raised for draft and meat purposes, are not typically used for milk production due to their low yield of 500-800 kg per lactation, averaging 2.0 ± 0.9 kg per cow per day. Despite the low production, buffalo milk in Thailand is considered high in quality, particularly in butterfat content, and is occasionally used in niche markets for cheese and other products.
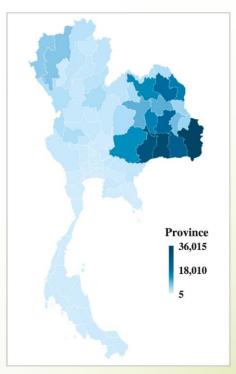

Figure 1: *Number of (1) buffalos and (2) buffalo farms in Thailand (Department of Livestock Development, 2023a).*

Buffaloes in Thailand are primarily raised as draft animals and for meat production rather than dairy. Buffalo meat, often considered a by-product rather than a primary product, has limited production data. However, the meat yield and quality of buffalo are comparable to beef, with dressing percentages ranging from 53% to 60%. Properly managed and fattened Thai swamp buffaloes produce high-quality meat, which has led to increased demand and growth in buffalo farming. This demand highlights the potential for buffalo meat as a significant contributor to Thailand's agricultural economy.

Over the past three decades, Thailand's buffalo population has shifted significantly. From an estimated 5.5 million in the 1970s, the population declined to approximately 1.3 million by 2023 (Figure 2; Department of Livestock Development, 2023a), due to mechanized agricultural practices, urbanization, and evolving farming methods. Recently, however, there has been a resurgence in buffalo farming, driven by market demand for buffalo meat and initiatives to revitalize the industry. This resurgence highlights the sector's resilience and potential for growth.

The Thai Swamp Buffalo Conservation and Development Day 2024, held on January 13-14 in Nakhon Ratchasima, aimed to improve buffalo breed quality, increase population, and enhance farmer incomes through traditional practices. This study measured the body weight (BW), withers height (HT), heart girth (HG), and body length (BL) of 150 buffaloes across different age groups and colors. Results showed significant growth in all categories. Black females had BW from 495.13 ± 128.08 kg at 10-18 months to 753.00 ± 144.22 kg at 24-36 months, while black males reached 1,097.90 ± 179.59 kg at 36-48 months. Pink females ranged from 493.33 ± 59.97 kg at 10-18 months to 719.00 ± 4.24 kg at 36-48 months, and pink males from 507.67 ± 86.21 kg at 10-18 months to 837.50 ± 84.36 kg at 36-48 months.
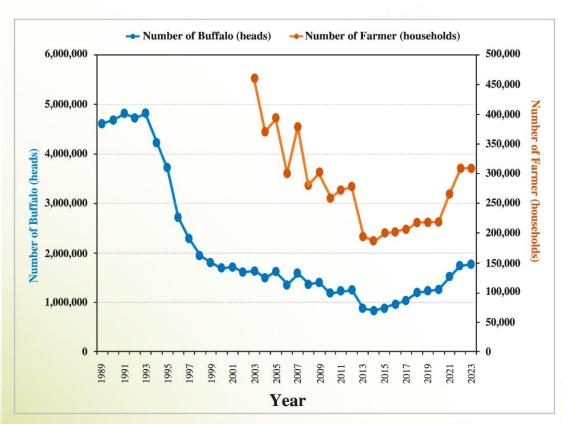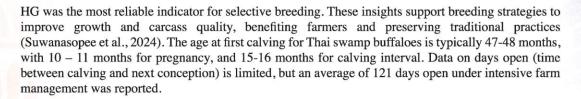

Figure 2: Buffalo population (Department of Livestock Development, 2023a).

HG was the most reliable indicator for selective breeding. These insights support breeding strategies to improve growth and carcass quality, benefiting farmers and preserving traditional practices (Suwanasopee et al., 2024). The age at first calving for Thai swamp buffaloes is typically 47-48 months, with 10 – 11 months for pregnancy, and 15-16 months for calving interval. Data on days open (time between calving and next conception) is limited, but an average of 121 days open under intensive farm management was reported.

3. Buffalo Farming Systems: Past and Present

Historically, buffalo farming in Thailand operated within extensive and transhumant systems, relying on natural pastures and seasonal migration. This labor-intensive system was dependent on communal grazing lands, with buffaloes primarily used for draught power in rice paddies (Chantalakhana, 2000; Uriyapongson, 2013). Today, buffalo farming has transformed into semi-intensive and intensive commercial approaches. Modern farms employ enhanced management practices, including improved housing, nutrition, and healthcare. Semi-intensive systems combine traditional grazing with supplementary feeding and controlled breeding to improve herd genetics and productivity. Intensive systems, though less common, emphasize high-yield production with substantial investments in infrastructure and technology advancements (Yaemkong et al., 2017).

Smallholder farmers still face challenges such as resource scarcity, parasites, disease outbreaks, and economic competition from other livestock sectors. However, governmental support and market demand for buffalo products offer promising prospects. Sustainable practices, resource accessibility, and technological adoption are crucial for increasing productivity and economic viability (Borghese et al., 2022).

4. Nutrition and Healthcare Services for Buffaloes

Thai swamp buffaloes primarily consume fibrous plant materials supplemented with concentrates or silage during low-forage quality periods. Proper nutrition management is essential for growth, reproduction, and health, particularly during critical stages like pregnancy and lactation (Paul, 2011).

Maintaining buffalo health is crucial for productivity and economic viability. Buffaloes are susceptible to diseases such as Bovine Tuberculosis and Foot and Mouth Disease, with limited access to affordable veterinary services impacting disease prevention and treatment. Enhancing veterinary infrastructure and services in rural areas is critical for improving disease management (Sukkasem et al., 2019).

Challenges like limited grazing land and high feed costs present obstacles to optimal nutrition. Economic constraints further limit investments in modern farming practices and veterinary care. However, opportunities in sustainable agriculture practices and technological innovations can enhance nutrition and disease management. Government support through policies, subsidies, and infrastructure development will be crucial for fostering a resilient buffalo farming sector.

5. Buffalo Breeding and Improvement Systems

Thai swamp buffaloes in black and pink colors exhibit unique characteristics (Figure 3) suited to their environment and traditional agricultural roles (Kongsuk et al., 2023). Their short face, flat forehead, and convex eyes enhance their field of vision, which is crucial for predator detection and ood acquisition. The distinctive "Chevlon" or V-shaped white fur on their necks aids in reaching food sources and may play a role in temperature regulation or mating displays. Robust musculature n their shoulders and chest supports movement and labor-intensive tasks, reflecting their historical role in Thai agriculture.

Buffalo breeding in Thailand focuses on enhancing the quality of genetics and production (meat and milk). Genetic evaluation programs use pedigree and performance data to assess genetic potential for traits like growth, disease resistance, and productivity. Molecular genetics and genomics techniques further enhance precision in identifying desirable traits (Burrow and Goddard, 2023), Studies indicate moderate to high heritability estimates for growth and reproductive traits, emphasizing their importance in breeding strategies (Chantalakhana, 2000, Thevamanoharan et al., 2000). Maintaining genetic diversity is essential for

long-term health and adaptability, and conservation efforts are needed to preserve valuable genetic material. The Thai swamp buffalo is crucial for Thai agriculture, providing labor, meat, milk, hides, and dung, but productivity has been low due to inadequate genetic improvement. Sangjong et al. (2024) estimated genetic parameters for growth traits using data from 1,652 buffaloes across 42 farms. Heritability for weight at various ages ranged from 0.08 to 0.69, with mostly positive genetic correlations, indicating significant genetic influence on growth traits and opportunities for effective selective breeding. Improved breeding programs can enhance growth rates and productivity, increase farmer incomes, and support sustainable agricultural development in Thailand.

Figure 3: Two of the five Thai swamp buffalo models in 2024: Big Buriram (black) and Kaew Fa (pink).

Government programs such as the Buffalo Breeding Scheme and Genetic Improvement Program (Department of Livestock Development. 2023b) aim to promote selective breeding and advanced genetic techniques. These initiatives, supported by research and development, enhance genetic quality and production efficiencies. Conservation efforts, including gene banks, are critical for preserving genetic diversity.

6. Marketing of Buffalo and Buffalo Products

The marketing of buffalo and buffalo products is vital for Thailand's agricultural economy. Products such as buffalo meat, milk, and hides generate significant income for rural communities and contribute to food security. Key marketing channels include local markets, slaughterhouses, and processing facilities.

Between 2020 and 2023, Thailand's buffalo trade saw considerable fluctuations. Live buffalo imports peaked in 2021 with 23,332 heads valued at 599.4 million THB (Thai baht) but dropped to 5,999 heads valued at 140.8 million THB in 2023. Similarly, imports of salted buffalo hides decreased from 3,017,690 kg in 2020 to 508,084 kg in 2023, with values falling from 48.2 million THB to 13.3 million THB. The export of live buffalo peaked at 61,966 heads valued at 1.17 billion THB in 2021, then declined to 31,592 heads valued at 614.5 million THB in 2023 (Department of Livestock Development, 2023c).

Despite its potential, buffalo product marketing faces challenges like limited infrastructure and distribution networks. Government initiatives aim to improve market access and infrastructure. Advances in genetic evaluation and breeding also enhance product value and competitiveness (Abdel-Shafy et al., 2021; Burrow and Goddard, 2023). Future efforts should focus on addressing infrastructure challenges, enhancing market linkages, and leveraging genetic advancements to maximize the economic potential of buffalo products while preserving cultural heritage and supporting rural livelihoods.

7. Future Improvement Programs

The future of buffalo improvement programs in Thailand involves collaborative efforts between the private sector, public institutions, and research organizations. Advancements in genetic evaluation technologies, including genomic selection and marker-assisted breeding (Burrow and Goddard, 2023), will play a pivotal role. Government policies supporting genetic improvement and sustainable practices infrastructure (Department of Livestock Development. 2023b) will be crucial for the sector's growth. Future programs will focus on sustainable agriculture practices, resource optimization, and environmental resilience (Abdel-Shafy et al., 2021). Continued investment in research and innovation will drive advancements in Buffalo improvement. Collaborative partnerships between academia, government agencies, and the private sector will facilitate knowledge exchange and accelerate innovation.

Conclusion

Buffaloes in Thailand have long been integral to the agricultural sector, playing vital roles in rice cultivation, meat and milk production, and rural livelihoods. Despite challenges, recent initiatives and technological advancements aim to rejuvenate the industry. Moving forward, sustainable practices and supportive policies are essential for ensuring the resilience and sustainability of Thailand's buffalo farming sector. These efforts will uphold cultural heritage, strengthen agricultural sustainability, and support rural economies.

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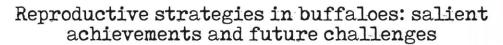
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SCIENTIFIC SESSION

BREEDING
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Reproductive strategies in buffaloes: salient achievements and future challenges

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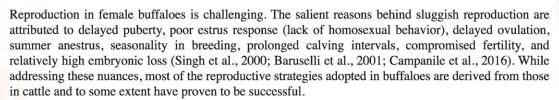*Corresponding author: nasimahmad@uvas.edu.pk

Abstract

The population of buffalo exceeds 200 million globally, 90% of them are housed in India, Pakistan, China, and Bangladesh. In South Asia, buffalo is an integral component of the rural economy. Despite having promising contributions to milk and meat production, reproduction is challenging. A shortage of breeding bulls (recommended 1:30 vs. existing 1:140) makes reproduction and genetic exploitation difficult. In addition, infertility in buffalo bulls was reported to be 35% including genetic, infectious, and management causes. Standards for puberty (22 months), body growth, sexual behavior, scrotal circumference, semen quality, and fertility were comprehensively developed. Numerous research works have been published in buffalo semen processing and cryopreservation for improved post-thawed quality, fertility and leading to commercialization. Despite this intensive work, the adoption of artificial insemination (AI) in buffalo remained low. The ongoing progeny testing programs in various buffalo rearing countries need to be strengthened in terms quality and quantity. However, the paucity of well-organized buffalo breeding associations, commercial farming, and poor implementation of breeding policies are the major hindrances. Buffalo females are generally considered to be sluggish reproducers due to delayed age of puberty, poor estrus expression (lack of homosexual behaviour), low fertility, and higher incidence of pregnancy losses. Typically, buffaloes are not seasonal; however, peak breeding happens from July to September in South Asia and late summer to early autumn in China and Italy. Surprisingly, pregnancy rates using natural services are around 63% in the breeding season, which dropped to 48% in the low breeding season. Interestingly, the pregnancy by artificial insemination (PAI) is 45% in the breeding season compared with 35% in the low breeding season. The higher (53%) PAI was achieved when buffaloes were inseminated 24 hours after the onset of standing estrus, which led to the development of the AM-AM rule. Estrus induction was possible by administration of prostaglandin F2 alpha with acceptable PAI (40%) but effective only in cyclic buffaloes. With the advent of progesterone-based devices, several protocols emerged with reasonable fertility (~40%), even during the low breeding season. The PAI was improved when new follicle waves were initiated or ovulation-inducing agents were incorporated into the CIDR protocol. Pregnancy loss was higher in buffaloes, especially in the low breeding season. Strategies to reduce pregnancy losses by ovulation-inducing agents or progesterone administration after insemination showed promising results. The reproductive biotechnologies like in-vivo derived (IVD) embryos were attempted in buffaloes but not with favorable outcomes, likely because of less primordial follicle reserves. On the other hand, sex semen and in-vitro produced (IVP) embryos by ovum pickup (OPU) are expanding commercially and have a promising future for the genetic progress in buffalo. Buffalo cloning has been demonstrated successfully at the experimental level. Taken together, the solutions to reproductive problems are available with acceptable fertility. However, their application to smallholder buffalo farming remains challenging. Alternatively, in future, the modernization and innovations in buffalo reproduction will be dependent on the commercialization of its products.

Keywords: Male & female reproduction, artificial insemination, synchronization, pregnancy losses, reproductive biotechnologies, buffaloes.

Introduction

Buffaloes play a pivotal role in the agricultural economies of many countries, especially in Asia, by producing milk, meat, and draught power. The buffalo are considered an excellent convertor of low-quality roughage and very well adapted to harsh climates (Gordon, 1996). According to the FAO (2024), the world buffalo population exceeds 205 million heads, with over 90% in Asia, including India, Pakistan, China, and Bangladesh.

KEYNOTE–BREEDING AND REPRODUCTION

Reproduction in female buffaloes is challenging. The salient reasons behind sluggish reproduction are attributed to delayed puberty, poor estrus response (lack of homosexual behavior), delayed ovulation, summer anestrus, seasonality in breeding, prolonged calving intervals, compromised fertility, and relatively high embryonic loss (Singh et al., 2000; Baruselli et al., 2001; Campanile et al., 2016). While addressing these nuances, most of the reproductive strategies adopted in buffaloes are derived from those in cattle and to some extent have proven to be successful.

Buffalo males, after birth, during their growth phase are generally ignored in terms of feeding and management. A great majority are often sold, and some even slaughtered at early age (personal communications). Consequently, the availability of breeding bulls becomes short, and puberty is delayed. This review will briefly cover the onset of puberty, spermatogenesis, semen characteristics, sexual behavior, development of normal indices for buffalo bull selection, and cryopreservation, and the addition of various chemicals to enhance post-thaw motility and fertility. Infertility in buffalo bulls has been discussed as well.

The current review is focused on the challenges and opportunities in buffalo reproduction. Furthermore, insights are provided on the salient achievements of the reproductive biotechnologies and their potential adaptation. However, the clinical aspects of male and female buffalo reproduction are beyond the scope of the current review.

1. MALE REPRODUCTION

1.1. Artificial insemination

Artificial insemination (AI) is the first reproductive biotechnology used in buffalo resulted in the birth of a calf in 1943 (Bhattacharya, 1962, Vale et al. 2022). It is an excellent tool for rapid genetic improvement as unequivocally demonstrated in Holstein. Initially, AI was introduced using liquid semen (Sansone et al. 2000), frozen semen (Singh and Balhara 2016), and sexed semen (Presicce et al., 2005) in buffaloes. Adaptation of AI as per estimates is around 25% in buffalo in Pakistan. Estrus detection difficulty because of the lack of homosexual behavior, and anatomical and seasonal variations in buffaloes are major reasons for the less adaptability of AI in the field (Borghese 2010). On commercial buffalo farms in Bulgaria and Canada, over 80% of the breeding is accomplished by AI. The pregnancy per AI (PAI) with frozen semen was lower than liquid semen in buffaloes (Andrabi 2009). The PAI with frozen semen ranged from 31 to 53% in buffaloes in the literature, however, it is only 29% in the field conditions (Anzar et al., 2003). The low fertility after AI might be attributed to the timing of insemination, estrus signs, semen quality, feeding, housing management, inseminator` skill, and different agro-ecological zones (Anzar et al., 2003). Interestingly, pregnancy through natural service in the breeding season (winter) was 63% only whereas in the low breeding season (summer), it is not more than 43% (Qayyum et al., 2018).

Table 1: Standards for body weight, scrotal circumference, sexual behavior, semen quality, and fertility in Nili Ravi buffalo bulls

Variables	Least square means ± SEM
Puberty	
Age at puberty, month	22.8 ± 1.1
Body weight, kg	419 ± 19
Scrotal circumference, cm	24.9 ± 0.5
Behavioral appearance to onset of puberty, months	
Sexual interest	8.0
Mounting	6.0
Penile protrusion	1.0
Adult	
Body weight, kg	770 ± 5
Scrotal circumference, cm	31.9 ± 2.0
Reaction time[1], second	19 ± 4
Semen volume, mL	2.9 ± 0.2
Concentration, million/mL	1050 ± 30
Motility, %	63 ± 5
Sperm abnormality, %	6.0 ± 0.8
Pregnancy per AI, %	45.8 ± 2.1

[1]The reaction time is measured from when the bull enters the arena till the first mount. The data is adopted from Ahmad (1987), Ahmad et al., (1989) and Anzar et al., (1993).
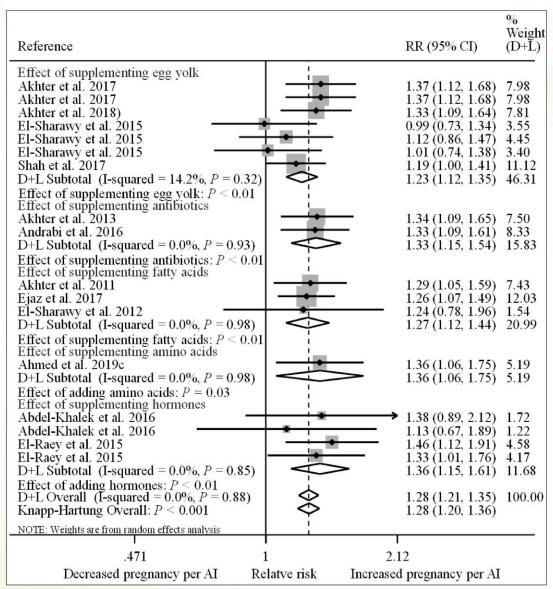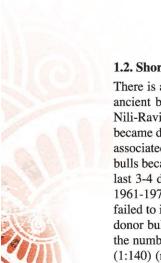
Figure 1: *The forest plot represents the effect of adding various additives in the extended semen on pregnancy per AI (PAI) in buffaloes. The forest plot was generated in the STATA software (STATSE, ver.14.1) by using the METAN procedure. The control (CON) group was adjusted as a reference (without any addition of additive), whereas supplementation of an additive such as egg yolk, antibiotics, fatty acids, amino acids, or hormones in the extended semen was considered as a treatment group in the comparative analysis. Each black diamond having a black horizontal line represents the point estimate or effect size [relative risk (RR)] with respect to its 95% confidence interval (CI). The central black line indicates no effect of an intervention or treatment, and point estimates moving left to the central line indicate a decrease in pregnancy per AI, whereas point estimates directing towards the right side represent an increase in pregnancy per AI. The size of the grey square box reflects the relative weighting of the treatment to the overall effect size estimate with larger squares representing greater weight. The overall effect size and 95% CI are indicated by the respective diamonds at the bottom, which are adjusted according to the DerSimonian and Laird (D+L) and Knapp-Hartung meta-analytical methods for random effects models. Overall, any additive such as egg yolk, antibiotics, fatty acids, amino acids, or hormones, when added into the extended semen, increased the relative risk (RR = 1.28; 95% CI = 1.20 to 1.36) of pregnancy per AI in dairy buffaloes. The heterogeneity measure, I2, is a measure of variation beyond chance among treatments included in the meta-analysis. The overall effect of supplementing additives on pregnancy per AI in buffaloes was homogenous, as indicated by the I2 of 0.0%.*

1.2. Shortage of breeding bulls

There is a well-known ancient saying that "the bull is half the herd". The remarkable intelligence of the ancient breeders in the selection and use of outstanding breeding bulls has led to the development of Nili-Ravi, Murrah, and Kundi as the best dairy breeds. However, the maintenance of breeding bulls became difficult and so was the maintenance of normal fertility. Besides management problems that were associated with the detection of estrus for mating at the right time, the acute shortage of qualified breeding bulls became a major source of increased infertility. Buffalo population increased significantly during the last 3-4 decades while the number of breeding bulls decreased in the same fashion (15% in India from 1961-1972). Despite artificial insemination was introduced in the country in 1955 in Pakistan, however, failed to improve buffalo productivity over the last 65 years. The main reason for this has been the use of donor bulls without exactly known genetic value. According to a survey in Punjab province in Pakistan the number of breeding bulls (44,633) for a breeding population of 6.21 million buffaloes was quite low (1:140) (recommended is 1: 30) and most of them were selected and raised by the breeders themselves without any performance or progeny testing (Ahmad, M. 2004, personal communication). It is expected the situation would not be different in other buffalo rearing countries of south Asia.

1.3. Infertility in buffalo bulls

Infertility or subfertility is the major cause of low reproductive efficiency in the buffaloes (Ahmad et al., 1985; Ahmad et al., 1987). Three types of infertility were reported in buffalo bulls. Type I infertility, the bulls did not show sexual activity, in type II, the bulls showed late onset of puberty having poor semen quality and not improvable, and whereas, in Type III infertility, the bulls produced normal semen initially which deteriorated later. Anatomical, histology, microbiological examination revealed genetic and infectious causes for type I and II whereas infectious for type III (Ahmad et al., 1985; Ahmad et al., 1987). Based on these findings, it is recommended to include the breeding soundness examination before the start of the breeding for natural bulls and at the semen production unit for AI bulls. Additionally, these infertility problems can be minimized by good feeding and management of the breeding buffalo bulls.

1.4. Reproductive indices developed in buffalo bulls

Reproductive standards body weight, scrotal circumference, sexual behavior, semen quality, and fertility in Nili Ravi buffalo bulls were developed and summarized in Table 1. The longitudinal studies under optimal feeding and management conditions were conducted in buffalo bulls. The criteria to define puberty was when a bull ejaculate contains 50×10^6 spermatozoa with minimum 10% motility (Wolf et al., 1965). Though, the average age of puberty was 22.8 ± 1.1 (range 16 to 30) months. The maximum growth of the body and scrotum takes place between 8 to 15 months of age. Although the onset of puberty is 22 months, spermatogenesis is established at 18 months of age (Ahmad et al., 2010). These data were consistent with earlier work where a good relationship between body growth, age, scrotal circumference, and puberty in Swamp (McCool and Entwistle, 1989), Murrah (Pant et al., 2003) and Nili Ravi Buffalo bulls (Ahmad et al., 1989; Ahmad et al., 1991).

Novel findings about the reproductive behavior of the buffalo bulls around puberty is presented in Table 1. It is evident that puberty can be predicted based on behavioral signs. Buffalo bulls start sexual interest, mounting, and penile protrusion at 8, 6, and 1 month before the onset of puberty, respectively. By following these recommendations, the performance tested bulls were capable of yielding semen around two years of age at semen production units. Sexual behavior is influenced by the genetic make of buffaloes (Yassen and Mahmaoud 1972). Moreover, age, environment, and management also play crucial roles in variation of sexual behavior (Vale, 1994, 1997). Buffalo bulls show Flehmen response and penile protrusion (Johari 1960; Anzar et al., 1993; Samo et al., 2005).

Later, the follow-up studies revealed normal standards of body growth, scrotal circumference, behavior, semen characteristics, and fertility by AI in buffalo bulls (Table 1). The adult buffalo bulls attain a body weight of an average 770 ± 5 kg, and a scrotal circumference of 31.9 ± 2.0 cm. A normal ejaculate of a buffalo bull contains 1050 ± 30 million/mL spermatozoa with over 60% motility, and around 6% sperm abnormalities. The pregnancy per AI of buffalo bull with good reproduction is not less than 45%.

Table 2: *Characteristics of studies reporting the data of pregnancy per AI that were included in the meta-analyses.*

References	Season	Breeding	Cyclicity	Treatment	Pregnancy per AI, %(n/n)
Feng et al., (1990)	-	TAI	-	PRID	25 (15/61)
Diaz et al., (1994)	-	TAI	0, 1	3mg norgestomet for 12 days and injected with 3mg norgestomet and 5mg oestradiol, PGF-PGF	67 (10/15), 84 (16/19)
Singh et al., (2000)	-	TAI	-	PGF-PGF	41 (26/63)
Berber et al., (2001)	-	TAI	-	GnRH-PGF-GnRH, GnRH-PGF-LH	56 (87/154), 64 (97/151)
de Araujo Berber et al., (2002)	-	TAI	1	GnRH-PGF-GnRH, GnRH-PGF-LH	56 (87/154), 64 (97/151)
Presicce et al., (2004)	-	TAI	-	PRID	20 (2/10)
Campanile et al., (2005)	-	TAI	-	GnRH-PGF-GnRH	54 (131/243)
RaviKumar et al., (2005)	-	TAI	0	GnRH-PGF-GnRH, CIDR IN-GnRH-PGF-CIDR Out-GnRH	33 (4/12), 42 (5/12)
Paul and Prakash (2005)	PBS	TAI	-	GnRH-PGF-GnRH	33 (5/15)
Francillo et al (2005)	-	TAI	-	GnRH-PGF-GnRH, PGF-PGF	92 (62/67), 91 (62/68)
Ali & Fahmy (2007)	-	TAI	1, 0	GnRH-PGF-GnRH	50 (5/10), 25 (2/8)
Sathiamoorthy et al., (2007)	-	TAI	-	PGF, CIDR, GnRH-PGF-GnRH	53 (8/15), 47 (7/15), 67 (10/15)
Baruselli et al., (2010)	LBS	TAI	-	GnRH-PGF-GnRH	28 (11/39)
Warriach et al., (2008)	PBS, PBS LBS, LBS	AIDE	-	PGF, GnRH+2PGF+GnRH, PGF, GnRH+ 2PGF+GnRH	48 (25/52), 28 (8/29) 38 (15/39), 23 (7/31)
Yuan et al., (2008)	-	TAI	-	PGF-PGF	42 (11/26)
Warriach et al., (2008)	-	TAI	1, 1, 0, 0	CIDR IN-GnRH-PGF-eCG-CIDR Out-GnRH, CIDR IN-GnRH-PGF-CIDR Out-GnRH	45 (5/11), 36 (5/14) 38 (8/21), 21 (4/19)

References	Season	Breeding	Cyclicity	Treatment	Pregnancy per AI, %(n/n)
Chaikhun et al., (2010)	-	TAI	-	GnRH-PGF-GnRH	33 (18/55)
Karen & Darwish (2010)	LBS	TAI	1,0	GnRH-PGF-GnRH	18 (2/11), 0 (0/10)
Naseer et al., (2011)	LBS, PBS PBS, PBS	AIDE, TAI TAI, TAI	-	CIDR IN-PGF- CIDR OUT CIDR IN-PGF- CIDR OUT + EB CIDR IN-PGF- CIDR OUT + GnRH CIDR IN-PGF- CIDR OUT	17 (11/65), 59 (10/17) 61 (11/18), 30 (6/20)
Yendraliza et al., (2011)	-	TAI	-	GnRH-PGF	100 (20/20)
Cai et al., (2011)	-	TAI	-	CIDR IN- CIDR Out, CIDR IN-PGF-CIDR Out-GnRH, CIDR IN-PGF-CIDR Out-GnRH-PGF	56 (13/23), 53 (16/30), 4 (16/40)
Derar et al., (2012)	PBS	TAI	1	GnRH-PGF-GnRH (Primiparous) GnRH-PGF-GnRH (Parous)	62 (429/686), 60 (131/219)
Akhtar et al., (2013)	PBS	TAI	1	PGF-GnRH-PGF-48GnRH, PGF-GnRH-PGF-EB-48GnRH, PGF-GnRH-PGF-72GnRH PGF-GnRH-PGF-EB-72GnRH	30 (3/10), 40 (4/10) 40 (4/10), 30 (3/10)
Alyas et al., (2013)	LBS	TAI	-	GnRH-PGF-GnRH, CIDR IN-GnRH-PGF-CIDR Out-GnRH	33 (2/6), 66 (4/6)
Naveed et al (2022)	LBS	TAI	-	CIDR IN-PGF + N/S- CIDR OUT CIDR IN-PGF + eCG- CIDR OUT	24 (11/45), 53 (23/43)
Hoque et al., (2014)	PBS	TAI	-	GnRH-PGF-GnRH, PGF - GnRH -PGF -GnRH GnRH – PGF –GnRH –GnRH – PGF – GnRH	28 (7/25), 36 (8/22), 44 (8/18)
Rossi et al., (2014)	LBS, PBS	TAI	-	GnRH–PGF–GnRH+Resynch with ovsynch	46 (115/250), 49 (203/414) 52 (230/444), 47 (112/240)

References	Season	Breeding	Cyclicity	Treatment	Pregnancy per AI, %(n/n)
Mirmahmoudi et al., (2014)	PBS	TAI	1, 1, 0, 0	PGF–GnRH–PGF–EB, GnRH–PGF–EB	55 (16/29), 36 (9/25) 50 (8/16), 27 (4/15)
Yousuf et al., (2015)	PBS	TAI	0	CIDR IN-PGF- CIDR OUT +EB (Nulliparous) CIDR IN-PGF- CIDR OUT (Nulliparous) CIDR IN-PGF-CIDR OUT +EB (Parous) CIDR IN-PGF- CIDR OUT (Parous)	38 (17/45), 41 (19/46) 54 (55/101), 47 (50/106)
Haider et al., (2015)1	PBS	TAI	0	CIDR IN-PGF- CIDR OUT + GnRH CIDR IN-PGF- CIDR OUT+AI	50 (8/16), 10 (5/50), 59 (10/17) 37 (19/51), 18 (3/17), 40 (20/50)
Kalwar et al., (2015)	-	TAI	-	CIDR IN-GnRH-PGF-CIDR Out-GnRH	53 (9/17)
Devipriya et al., (2015)	-	AIDE	0	P4 sponge in-PGF-P4 sponge out	53 (16/30)
Waqas et al., (2016)	PBS	TAI	1	GnRH-PGF-GnRH, PGF-GnRH-GnRH-PGF-GnRH	24 (6/25), 56 (14/25)
Arshad et al., (2017)	PBS	TAI	1	CIDR IN-PGF- CIDR OUT + GnRH CIDR IN-PGF- CIDR OUT + GnRH +P4 CIDR IN-PGF-CIDR OUT + GnRH + GnRH	41 (26/63), 51 (28/55), 63 (40/63)
Qayyum et al., (2018)	PBS	TAI	-	PBS + AI, LBS + AI	25 (17/40), 32 (8/25)
Riaz et al., (2018)	PBS	AIDE	-	AI at 0, 12, 24, 36 h after onset of estrus	26 (8/30), 37 (10/27) 53 (15/28), 12 (3/24)
Khan et al., (2018)	PBS	TAI	-	CIDR IN-EB- PGF+eCG- CIDR out-EB CIDR IN-EB- PGF- CIDR out-EB	57 (25/44), 30 (13/43)
Gabriel et al., (2019)	-	TAI	-	CIDR IN-GnRH-Dinoprost-Tromethamine-CIDR Out-HCG, CIDR IN-GnRH-Chloprostenol-CIDR Out-HCG, CIDR IN-GnRH-D-Chloprostenol-CIDROut-HCG	36 (18/50), 4 (20/50), 36 (18/50)

References	Season	Breeding	Cyclicity	Treatment	Pregnancy per AI, %(n/n)
Atabay et al., (2020)	-	TAI	-	PGF, PGF-GnRH, PGF-GnRH, PGF-GnRH-HCG	21 (16/76), 37 (24/65) 36 (21/59), 39 (24/62)
Carvalho et al., (2013)	LBS	TAI	-	P4-PGF-eCG-GnRH, P4-PGF-GnRH	53 (68/129), 39 (50/129)
De Rensis et al., (2005)	-	TAI	0, 0, 1, 1	OVS, P4+OVS	5 (1/21), 30 (6/20) 35 (22/62), 51 (34/66)
Barile et al., (2001)	LBS	TAI	-	P4-PMSG	65 (26/40)
Neglia et al., (2003b)	LBS	TAI	1, 1, 0, 0	OVS, PRID-EB-PGF-PMSG	44 (37/84), 28 (28/100) 50 (3/6), 55 (5/9)
Monteiro et al., (2016)[2]	PBS	TAI	-	EB-P4-PGF-eCG-GnRH	64 (31/48), 70 (33/47), 61 (29/47)
Carvalho et al., (2014)[2]	PBS	TAI	0	EB-P4-PGF-eCG-GnRH	55 (62/111), 55 (67/121), 48 (57/118)
Carvalho et al., (2007)[3]	LBS	TAI	-	EB-P4-PGF-eCG-GnRH EB-P4-PGF-eCG-hCG	54 (31/57), 49 (33/67) 49 (27/55), 55 (35/63)
Amin et al., (2019)	LBS	AIDE	0	CIDR-PGF	60 (15/25)
Samir et al., (2019)	-	AIDE	-	CIDR-PGF, CIDR-OVS	50 (9/18), 67 (12/18)
Ramesha et al., (2015)	-	AIDE	0	CIDR-EB	57 (287/500)
Carvalho et al., (2017)	LBS	TAI	-	P4-EB-PGF-EB24, P4-EB-PGF-EB36 P4-EB-PGF-GnRH	4845 (76/168), 43 (74/172) 50 (85/171)
Otava et al., (2021)	-	TAI	-	OVS + Resynch	84 (48/57), 72 (36/50), 94 (17/18) 70 (37/53), 79 (49/62), 58 (57/98) 88 (51/58), 73 (29/40), 79 (74/94) 74 (67/90)

References	Season	Breeding	Cyclicity	Treatment	Pregnancy per AI, %(n/n)
Carvalho et al., (2021)	PBS	TAI	0	ME-OVS, P4-OVS, OVS	23 (18/77), 60 (50/83), 17 (11/65)
Rajput et al., (2024)	PBS	AIDE	1	PGF, PGF + Stimvet	41 (7/17), 53 (9/17)
Rathore et al., (2017)	LBS	TAI	0	OVS, GnRH-PGF-EB, PMSG-OVS	26 (4/11), 10 (1/10), 22 (2/9) 21 (8/39), 20 (8/40), 29 (12/41)
Gallab et al., (2022)	LBS	TAI	0	OVS, GnRH-PGF-GnRH	20 (4/20), 60 (18/30)
Ramoun et al., (2017)	LBS	TAI	1	OVS, CIDR-synch, OVS-Insulin	46 (6/13), 50 (10/20), 67 (12/18)
Monteiro et al., (2018)	LBS, PBS	TAI	-	EB+P4-PGF-eCG-GnRH	54 (20/37), 63 (193/304)
Bhat et al. (2015)	-	TAI	-	EB+CIDR-PGF-GnRH, GnRH+CIDR-PGF-GnRH, CIDR-PGF-GnRH	84 (21/25), 76 (19/25), 40 (4/10)
Campanile et al., (2007)	PBS	TAI	1	OVS-GnRH on 5th day post AI, OVS-hCG on 5th day post AI, OVS-PRID on 5th day post AI, OVS	63 (46/73), 68 (51/75) 60 (46/77), 64 (44/69)
Campanile et al., (2013)	PBS	TAI	-	OVS	70 (47/67), 55 (47/85)
Di Francesco et al., (2012)	PBS	TAI	1	OVS	63 (82/131), 59 (74/125)
Ghuman et al., (2014)	LBS	TAI	0	OVS, CIDR-synch	30 (3/10), 66 (6/9)
Gupta et al., (2015)	-	TAI	0	OVS, OVS with double dose PG, OVS-Insulin, OVS with double dose PG-Insulin, Insulin-PGF-GnRH	60 (6/10), 70 (7/10), 80 (8/10) 80 (8/10), 80 (8/10)
Hussein et al., (2016)	PBS	TAI	1	CIDR-synch, OVS, PGF-PGF	35 (7/20), 40 (8/20), 35 (7/20)
Karuppanasamy et al., (2017)	PBS	TAI	0	2GnRH-PGF-EB, 2GnRH-PGF-GnRH	0 (0/10), 21 (3/14)
Phogat et al., (2018)	LBS	TAI	0	Mel-OVS	50 (10/20)
Neglia et al., (2016)	-	TAI	1	OVS-PGF, OVS	53 (96/180) 58 (67/116)

References	Season	Breeding	Cyclicity	Treatment	Pregnancy per AI, %(n/n)
Oropeza et al., (2010)	-	TAI	-	OVS, Presynch-OVS	35 (14/40), 45 (18/40)
Roy & Parakash (2009)	LBS	TAI	1	OVS, Ovs+ norploac	45 (5/11), 54 (6/11)
Russo et al., (2010)	-	TAI	1	OVS	49 (140/288)
Sharma et al., (2017)	LBS	TAI	0	OVS, eCG+OVS	23 (6/26), 34 (10/29)
Vecchio et al., (2010)	PBS	TAI	1	OVS-GnRH, OVS-hCG , OVS-P4	85 (44/52), 86 (44/51), 85 (40/47)
Chohan (1998)	PBS, PBS LBS, LBS	AIDE	1	PG 125ug IVSM, PG, 500ug IM	36 (10/28), 45 (15/33) 14 (5/37), 15 (6/39)
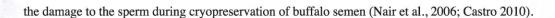
[1]Experiment reported the pregnancy per AI according to two methods of synchronization and three time points for insemination (48, 60, and 72h) after CIDR removal; [2]Experiments reported the pregnancy per AI according to new, single-time used and two-times used CIDR; [3]Experiment reported the pregnancy per AI according to synchronization method and new or used CIDR.

1.5. Cryopreservation of buffalo spermatozoa

Semen processing work including the frequency of collection, holding time, dilution, concentration, equilibration time, and freezing in buffalo has been optimized (Ahmad 1987). Cryopreservation protocol was first developed in the dairy industry in the early 1950's. However, buffalo cryopreservation started after 1970's. It is the non-physiological process by which living cells survive through thermal and osmotic stress during dilution, freezing, and thawing (Watson et al., 1992). Spermatozoa morphology and physiology are affected (Bailey et al., 2003) during each stage resulting in reduced motility, acrosome damage (Tuli et al., 1981), and changes in membrane integrity (Rasul et al., 2001).

The semen extenders and its composition has already been reviewed (Andrabi, 2009). The use of different combinations of extenders, antibiotics, others supplements, and their effect on fertility are presented in Figure 1. Overall, any additive such as egg yolk, antibiotics, fatty acids, amino acids, or hormones, when added into the extended semen, increased the relative risk (RR = 1.28; 95% CI = 1.20 to 1.36) of PAI in dairy buffaloes. Studies have shown that post thaw motility was variable with different extenders i.e., yolk citrate or skim milk 20%, lactose 30% TRIS 50 and TES 60% respectively. Moreover, TRIS (trisaminomethane) and TES (Hydroxy-methyl-amino-ethan) based extenders are suitable for buffalo semen cryopreservation (Vale et al., 2014).

The addition of antioxidants in the extended semen increased the relative risk (RR = 1.39; 95% CI = 1.29 to 1.50: P < 0.001) of PAI whereas the addition of cryoprotectants in the extended semen did not improve (RR = 1.12; 95% CI = 0.92 to 1.37; P = 0.26) fertility in buffaloes (Figure 2). The lethal effects of reactive oxygen species (ROS) on sperm were determined earlier by Macleod (1943). High ROS level reduces sperm fertility due to in loss of motility, sperm respiration, lesions in sperm DNA, and loss of intercellular enzymes (Gomez et al., 1998; Aitken and Baker 2002; Kardivel et al., 2009). These ROS effects can be decreased by adding antioxidants in the extenders of buffalo semen which has resulted in increased sperm motility, vigor and decrease

the damage to the sperm during cryopreservation of buffalo semen (Nair et al., 2006; Castro 2010).

1.6. Fertility with frozen thawed buffalo semen

Fertility is the crucial parameter to assess semen quality. Buffalo spermatozoa results in less fertility rate, more delicate and susceptible to freezing and thawing as compared to cattle (Chohan et al., 1992; Dhami et al., 1994), however, mechanistic answers are lacking. Fertility trials were conducted to find the relationship with sperm motility, viability and membrane integrity. The semen of twenty bulls were evaluated and buffaloes were synchronized with Ovsynch protocol for fixed time AI. It was concluded that that fertility has no relation with motility, viability and membrane integrity (Kumar et al., 2016). In contrast, kinematic parameter relationship show that fertility rate is higher and positively correlated with bulls having higher motility as compared to medium and low fertile bulls (Singh et al., 2017).

Recommendations for buffalo bull

1. Buffalo calf rearing incentivized schemes should be introduced to tackle the shortage of the breeding bulls.

2. The community bulls scheme should be strengthened to maximize the breeding efficiency in buffalo until AI predominate.

3. Implementation of breeding soundness evaluation proforma separately for natural and AI breeding bulls.

4. Screening of bulls for health, and infertility on regular basis.

5. Progeny testing program needs to be strengthened using digital technology.

6. Buffalo breeder associations require support from the Government through incentivized approaches.

7. Use of buffalo specific extender by the addition of anti-oxidants emerged from the latest research.

8. International or regional collaboration among buffalo rearing countries or establishment of mutual funding for buffalo research and development.

2. FEMALE REPRODUCTION

2.1. Puberty in buffalo

Female buffalo attain puberty after gaining over 60% (360 ± 13 kg) of adult body weight (Plansky and Dimitrov, 2020). However, the pubertal age varies from 18 to 46 months (Jainudeen and Hafeez, 1993), which is attributed to various factors, such as nutrition, management, climate, and genetics. By providing optimal conditions, riverine buffalo can reach puberty at 15-18 months whereas swamp buffalo at 21-24 months (Borghese, 2005). A recent study conducted in Nili Ravi buffalo heifers where authors fed a diet (crude protein at 18% of the concentrate and metabolizable energy at 0.5% of the body weight) started from 7 months of age has resulted in 24 ± 0.5 months' pubertal age and 403 ± 10 kg body weight at puberty (Saadullah et al., 2020). The delayed puberty can lead to late conception, ultimately low reproductive efficiency and extended non-productive periods. Poor feeding and management are the major causes of delayed puberty in the field.

2.2. Natural breeding vs. artificial insemination in buffalo

In buffaloes, natural services predominate as a method of breeding compared to artificial insemination (Thomas, 2008). The pregnancy per AI (PAI) in naturally bred buffaloes was higher (63%) than that of artificially inseminated (45%) buffaloes during peak breeding season (Qayyum et al., 2018). Artificial insemination has played a prominent role in genetic selection, disease control, and cost-effectiveness in breeding strategies for cattle (López-Gatius, 2012). Buffalo were thought to have comparable reproductive anatomy and physiology with cattle. Therefore, most breeding protocols were adopted from cattle, such as the traditional AM-PM rule during standing estrus, which was imposed on buffaloes. The consequences came in the form of increased service per conception and decreased PAI, leading to less adoption of AI by farmers (Drost, 2007). A classic experiment was conducted to address the question of

the timing of insemination with reference to the onset of the standing estrus in buffalo (Riaz et al., 2018). Interestingly, maximum PAI (53%) was achieved when buffalo were inseminated at 24 h after the onset of standing estrus. The timing of ovulation with reference to the standing estrus was 34.5 ± 0.96 h instead of 24 h in cattle. Hence, in buffalo, experiment conducted by Riaz et al., (2018) led to the development of the AM-AM rule instead of the AM-PM rule in cattle.

Reference	RR (95% CI)	% Weight (D+L)
Effect of supplementing antioxidants		
Ahmed et al. 2019b	1.18 (0.93, 1.49)	7.07
Ahmed et al. 2019b	1.34 (1.07, 1.68)	7.63
Ahmed et al. 2019d	1.32 (1.03, 1.68)	6.78
Ahmed et al. 2019d	1.39 (1.10, 1.76)	7.08
Ansari et al. 2016a	1.40 (1.06, 1.84)	5.71
Ansari et al. 2016a	1.38 (1.06, 1.80)	6.06
El-kon and Darwish 2011	1.71 (0.85, 3.44)	1.17
El-kon and Darwish 2011	1.57 (0.77, 3.22)	1.10
El-Razek and El-Shamaa 2016	1.62 (0.70, 3.73)	0.82
El-Razek and El-Shamaa 2016	1.81 (0.80, 4.06)	0.87
El-Razek and El-Shamaa 2016	1.50 (0.60, 3.74)	0.69
El-Razek and El-Shamaa 2016	1.25 (0.47, 3.33)	0.60
El-Razek and El-Shamaa 2016	0.75 (0.22, 2.52)	0.40
Iqbal et al. 2016a	1.42 (1.08, 1.87)	5.77
Iqbal et al. 2016b	2.57 (1.73, 3.80)	3.26
Iqbal et al. 2018	1.37 (1.04, 1.80)	5.87
Javed et al. 2019	1.30 (1.00, 1.69)	6.17
Rahman et al. 2015	1.38 (0.91, 2.10)	2.94
Wadood et al. 2016	1.75 (0.97, 3.16)	1.58
D+L Subtotal (I-squared = 0.0%, P = 0.69)	1.39 (1.29, 1.50)	71.57
Effect of supplementing antioxidants: *P* < 0.001		
Effect of supplementing cryoprotectants		
Abd Elmonem et al. 2019	0.73 (0.38, 1.42)	1.28
Abd Elmonem et al. 2019	0.31 (0.12, 0.81)	0.61
Akhter et al. 2012	1.35 (1.10, 1.66)	8.50
Shah et al. 2016a	1.16 (1.01, 1.34)	12.31
Qadeer et al. 2016	1.19 (0.78, 1.80)	3.00
Swelum et al. 2011	1.09 (0.59, 2.01)	1.49
Swelum et al. 2011	1.33 (0.68, 2.61)	1.25
D+L Subtotal (I-squared = 46.6%, P = 0.08)	1.12 (0.92, 1.37)	28.43
Effect of adding cryoprotectants: *P* = 0.26		
D+L Overall (I-squared = 20.7%, P = 0.17)	1.33 (1.23, 1.44)	100.00
Knapp-Hartung Overall: *P* < 0.01	1.32 (1.22, 1.42)	
NOTE: Weights are from random effects analysis		

.116 — 1 — 8.61

Decreased pregnancy per AI — Relative risk — Increased pregnancy per AI

Figure 2: *The forest plot represents the effect of adding various additives in the extended semen on pregnancy per AI in buffaloes. The forest plot was generated in the STATA software (STATSE, ver.14.1) by using the METAN procedure. The control (CON) group was adjusted as a reference (without any addition of additive), whereas supplementation of an additive such as antioxidants or cryoprotectants in the extended semen was considered as a treatment group in the comparative analysis. Each black diamond having a black horizontal line represents point estimate or effect size [relative risk (RR)] with respect to its 95% confidence interval (CI). The central black line indicates no effect of an intervention or treatment and point estimates moving left to the central line indicate a decrease in pregnancy per AI, whereas point estimates directing towards right side represent an increase in pregnancy per AI. The size of the grey square box reflects the relative weighting of the treatment to the overall effect size estimate with larger squares representing greater weight. The overall effect size and 95% CI are indicated by the respective diamonds at the bottom, which are adjusted according to the DerSimonian and Laird (D+L) and Knapp-Hartung meta-analytical methods for random effects models. Overall, the addition of antioxidants in the extended semen increased the relative risk (RR = 1.39; 95% CI = 1.29 to 1.50: P < 0.001) of pregnancy per AI in dairy buffaloes, whereas the addition of cryoprotectants in the extended semen did not improve fertility (RR = 1.12; 95% CI = 0.92 to 1.37; P = 0.26). The heterogeneity measure, I2, is a measure of variation beyond chance among treatments included in the meta-analysis. The overall effect of supplementing antioxidants in the extended semen on pregnancy per AI in buffaloes was homogenous, as indicated by the I2 of 0.0%, whereas a mild heterogeneous response was observed for the cryoprotectants in the extended semen (I2 = 46.6; P = 0.08).*

Pregnacy Per AI by Country in Buffalo
Data collected from published reviews

Source: Jusnain Lab
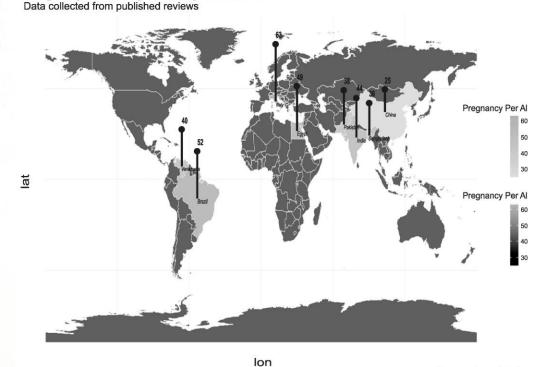
Figure 3: The world pregnancy map (synch-preg-map) represents the pregnancy per AI (PAI) by country in buffaloes. The data to generate the world preg-map were extracted from 74 published papers in well-reputed journals. Articles by countries included in the meta-analysis were India (n = 18), Italy (n = 15), Pakistan (n = 13), Brazil (n = 11), Egypt (n = 8), and 9 articles from China, Bangladesh, Venezuela etc reported that of 11,261 buffaloes from 1990 to 2024. The METAPROP procedure analyzed the data in the 'meta' package of the R statistical software (ver. 4.4.1). More than 95% of the articles reported the PAI through estrus synchronization. Key factors for enhancing synchronization that is good body condition, cyclicity, breeding season, hormonal interventions (CIDR-GnRH protocol), and the use of ultrasound for improved reproductive management. Variation is pregnancy in genetics, management, nutrition, and environment. The possible explanation of the data represented in the synch-preg-map is presented in subsequent Figures 7 to 10. The copyrights are with the author's permission.

2.3. Estrus synchronization in buffalo

Certain estrus or ovulation synchronization protocols, a tool to enhance reproductive management, were developed to address low fertility challenges in buffalo. Several of these have been adopted from cattle (De Rensis & López-Gatius, 2007; Carvalho et al., 2017). The estrus synchronization aimed to either shorten the luteal phase using a luteolytic agent (Lauderdale, 2009) or prolong the luteal phase using progestogen-based protocols. Seventy-four studies were considered to conduct a meta-analysis of PAI by country, synchronization, season, cyclicity, and breeding method in buffaloes (Table 2). Figure 3 depicts PAI according to country (synch-preg-map) in synchronized buffaloes that range from 25 to 63%. The data to generate the 'synch-preg-map' were extracted from 74 published papers in well-reputed journals. Articles by countries included in the meta-analysis were India (n = 18), Italy (n = 15), Pakistan (n = 13), Brazil (n = 11), Egypt (n = 8), and 9 articles from China, Bangladesh, Venezuela etc., reported that of 11,261 buffaloes from 1990 to 2024. The prostaglandins (PG) F2α were used to induce the estrus by causing luteolysis of the corpus luteum (CL) (Brito et al., 2002; Chantaraprateep, 1987; Kamonpatana et al., 1987).

Table 3: Characteristics of studies reporting the data of blastocyst rate, and pregnancy per ET that were included in the meta-analyses.

Reference	Country	Technique	Blastocyst rate, % (n/n)	Pregnancy per ET, % (n/n)
Kasiraj et al., 1993	India	IVD.ET	-	30 (32/105)
Madan et al., 1994	India	IVP.ET	4 (16/359)	25 (4/16)
Hufana et al., 2004	Philippines	IVP.ET	-	16 (9/55)
Hufana et al., 2007	Philippines	IVP.ET	-	13 (5/40)
Lu et al., 2006	China	IVP	23 (488/2106)	-
		IVP.ET	-	100 (1/1)
Liang et all., 2008	China	IVP.Vitri.ET	-	19 (27/142)
Laowtammathron et al., 2005	Thiland	SCNT.Vitri.ET	44 (18/41)	44 (18/41)
Saha et al., 2013	India	SCNT.Vitri.ET	-	21 (9/43)
Wani et al., 2004a	India	Vitri.IVP	2 (42/1955)	-
Abd Allah et al.,	Egypt	Vitri.IVP	17 (120/703)	-
El-shalofy et al., 2016	Egypt	Vitri.IVP	15 (51/336)	-
Gasparrini et al., 2007	Italy	Vitri.IVP	6 (36/639)	-
Boonkusol et al., 2007	Thiland	Vitri.IVP	15 (149/1023)	-
Gautam et al., 2008	India	SlowFr.IVP	4 (20/520)	-
		Vitri.IVP	5 (40/868)	-
Attanasio et al., 2009	Japan	Vitri.IVP	10 (57/583)	-
Attanasio et al., 2010	Italy	Vitri.IVP	7 (51/708)	-
Liang et all., 2011	Thiland	Vitri.Parth.IVP	15 (151/1022)	-
		Vitri.ICSI.IVP	8 (43/549)	-

Reference	Country	Technique	Blastocyst rate, % (n/n)	Pregnancy per ET, % (n/n)
Liang et all., 2012	Japan	Vitri.IVP	4 (35/969)	-
Wang et al., 2016	China	Vitri.ICSI.IVP	11 (41/381)	-
Liang et al., 2020	Thailand	IVP	19 (108/575)	-
George et al., 2011	India	SCNT.ET	29 (131/449)	19 (3/16)
Shah et al., 2009	India	SCNT, SCNT.ET	32 (197/609)	13 (3/23)
Shi et al., 2007	China	SCNT.ET	-	19 (4/21)
Lu et al., 2011	China	Parth.IVP	26 (193/730)	-
		SCNT	12 (95/787)	-
Panda et al., 2011	India	SCNT.ET	31 (94/302)	32 (6/19)
		SCNT.ET	11 (220/2092)	7 (3/43)
Saha et al., 2013	India	SCNT	38 (282/752)	-
		SCNT.Vitri.ET	-	21 (9/43)
Selokar et al., 2014	India	SCNT.ET	46 (459/993)	14 (3/22)
Tasripoo et al., 2014	Thiland	SCNT.ET	25 (157/628)	83 (10/12)
Jyotsana et al., 2015	India	SCNT.ET	22 (297/1325)	33 (1/3)
Madheshiya et al., 2015	India	SCNT.ET	46 (357/771)	20 (1/5)
Saini et al., 2016	India	SCNT.ET	44 (357/811)	10 (2/20)
Raja et al., 2019	India	SCNT.ET	23 (167/715)	13 (2/15)
Selokar et al., 2019	India	SCNT.ET	28 (195/705)	-

Reference	Country	Technique	Blastocyst rate, % (n/n)	Pregnancy per ET, % (n/n)
Shyam et al., 2020	India	SCNT,ET	42 (663/1571)	14 (8/57)
Konrad et al., 2017	Argentina	OPU,IVP	4 (8/224)	-
Marin et al., 2019	Brazil	OPU,IVP	-	21 (19/89)
Liang et al., 2008	China	OPU,IVP	16 (309/1973)	-
Manjunatha et al., 2008	India	OPU,IVP	21 (36/175)	-
Khaliq et al., 2024	Pakistan	IVP	35 (217/620)	-
Kabeer et al., 2024	Pakistan	IVP	9 (65/725)	-
Gupta et al., 2001	India	IVP	10 (177/1807)	-

Abbreviations;

IVD, iv-vivo derived embryos; IVP, in-vitro produced embryos; OPU, ovum pickup; ET, embryo transfer; ICSI, intra-cytoplasmic sperm injection; SCNT, somatic cell nuclear transfer; Vitri, Vitrified; Parth, Parthenogenesis; Slow Fr, Slow freezing.

The efficacy of PG to induce lysis of CL is greater when administered during the diestrus in buffalo (Chantaraprateep, 1987). The PG caused the decline of progesterone within 24 h after administration and consequently provided the opportunity for the dominant follicle to grow and ovulate within 3 to 7 days after treatment (De Rensis & Lopez-Gatius, 2007; Galina & Orihuela, 2007). The PG treatment at the random stage of the estrous cycle induces estrus in only 50% of the buffalo, and the remaining buffalo can be brought into estrus by administering another PG 11 to 13 days apart. Our meta-analytical approach has depicted that 37% PAI was achieved with single PG, while double PG resulted in higher (63%) PAI in buffaloes (Figure 4). However, caution should be taken as it works only in the cyclic buffaloes.

The incorporation of the gonadotropin-releasing hormone (GnRH) or luteinizing hormone (LH) in the estrus synchronization results in tightening of the ovulation window and facilitates fixed-time insemination. Figure 5 depicts PAI by ovulation synchronization protocol (OVS) in buffaloes. The standard OVS protocol resulted in 46% PAI in buffaloes, which is 7% higher than the single PG protocol. Replacing the last GnRH with LH resulted in improved PAI (64%), and replacing with estradiol benzoate (EB) decreased PAI (24%). However, caution should be taken as only a few studies reported the data. Interestingly, the incorporation of equine chorionic gonadotropin (eCG) yielded only 31% PAI and pre-synchronization prior to the start of OVS did not prove beneficial in buffaloes. During anestrus and low breeding season, OVS protocol resulted in low number of pregnancy in buffaloes (Ali & Fahmy, 2007; Baruselli et al., 2010; De Rensis et al., 2005). Ideally, a large size follicle on the ovaries is required for the better response with OVS and the success of the OVS protocol is higher when initiated at early diestrus (Vasconcelos et al., 1999; Bleach et al., 2004; Sartori et al., 2004; Burns et al., 2005; Perry et al., 2005; Souza et al., 2007).
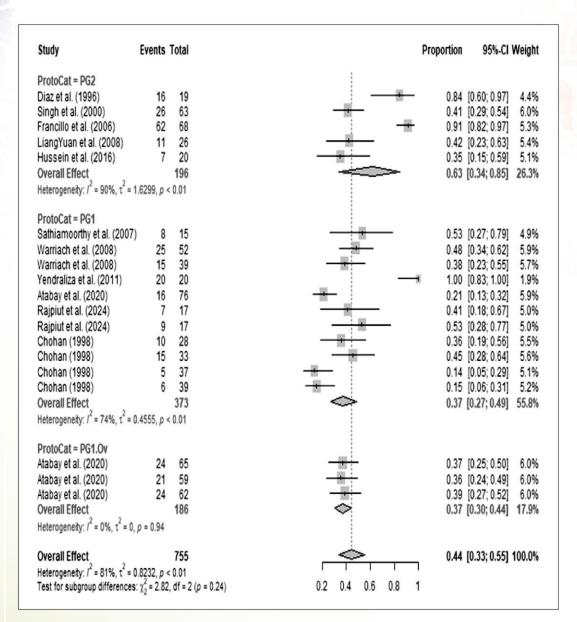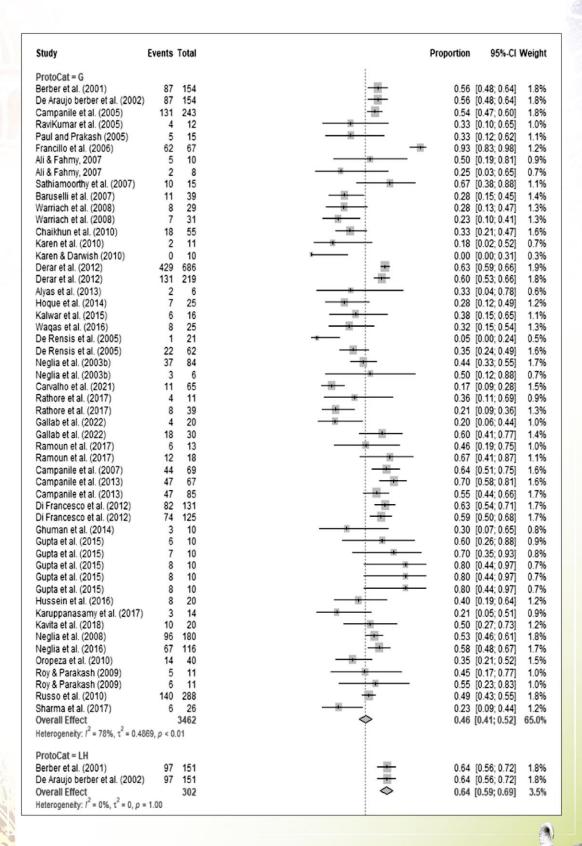
Figure 4: *The forest plot depicted the manipulation in prostaglandin (PG) synchronization and its effect on pregnancy per AI (PAI) in buffaloes. The reported dataset was extracted from the twelve studies reporting the data of 755 buffaloes. The METAPROP procedure analyzed the data in the 'meta' package of the R statistical software (ver. 4.4.1). The forest plot was generated through the forest function. Each black dot having a black horizontal line represents the effect size in proportion and its respective 95% confidence interval (CI). The central red dotted line indicates the overall proportion and point estimates moving left to the central line indicate a decrease in PAI. In contrast, point estimates directed towards the right side represent an increase in PAI. The size of the grey square box reflects the relative weighting of the comparison to the overall effect size estimate, with larger squares representing greater weight. The overall effect size and 95% CI are indicated by the respective diamonds at the bottom, which are adjusted according to the random effects models. Overall, synchronization by using the PG reported 37% PAI (95% CI = 33 to 55%). The subgroup analyses suggested no difference in PAI either by single or double PG (37 vs. 63%) in buffaloes. The addition of GnRH at the time of AI in the single PG did not benefit PAI (37%).*

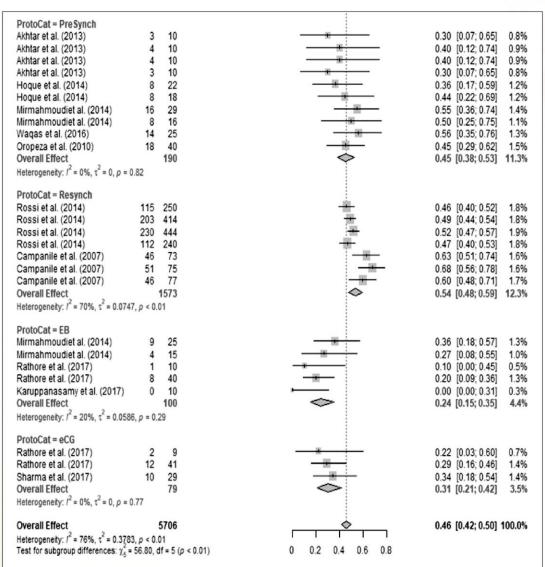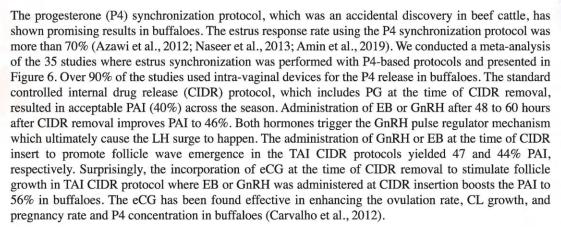| Study	Events	Total	Proportion	95%-CI	Weight
ProtoCat = G					
Berber et al. (2001)	87	154	0.56	[0.48; 0.64]	1.8%
De Araujo berber et al. (2002)	87	154	0.56	[0.48; 0.64]	1.8%
Campanile et al. (2005)	131	243	0.54	[0.47; 0.60]	1.8%
RaviKumar et al. (2005)	4	12	0.33	[0.10; 0.65]	1.0%
Paul and Prakash (2005)	5	15	0.33	[0.12; 0.62]	1.1%
Francillo et al. (2006)	62	67	0.93	[0.83; 0.98]	1.2%
Ali & Fahmy, 2007	5	10	0.50	[0.19; 0.81]	0.9%
Ali & Fahmy, 2007	2	8	0.25	[0.03; 0.65]	0.7%
Sathiamoorthy et al. (2007)	10	15	0.67	[0.38; 0.88]	1.1%
Baruselli et al. (2007)	11	39	0.28	[0.15; 0.45]	1.4%
Warriach et al. (2008)	8	29	0.28	[0.13; 0.47]	1.3%
Warriach et al. (2008)	7	31	0.23	[0.10; 0.41]	1.3%
Chaikhun et al. (2010)	18	55	0.33	[0.21; 0.47]	1.6%
Karen et al. (2010)	2	11	0.18	[0.02; 0.52]	0.7%
Karen & Darwish (2010)	0	10	0.00	[0.00; 0.31]	0.3%
Derar et al. (2012)	429	686	0.63	[0.59; 0.66]	1.9%
Derar et al. (2012)	131	219	0.60	[0.53; 0.66]	1.8%
Alyas et al. (2013)	2	6	0.33	[0.04; 0.78]	0.6%
Hoque et al. (2014)	7	25	0.28	[0.12; 0.49]	1.2%
Kalwar et al. (2015)	6	16	0.38	[0.15; 0.65]	1.1%
Waqas et al. (2016)	8	25	0.32	[0.15; 0.54]	1.3%
De Rensis et al. (2005)	1	21	0.05	[0.00; 0.24]	0.5%
De Rensis et al. (2005)	22	62	0.35	[0.24; 0.49]	1.6%
Neglia et al. (2003b)	37	84	0.44	[0.33; 0.55]	1.7%
Neglia et al. (2003b)	3	6	0.50	[0.12; 0.88]	0.7%
Carvalho et al. (2021)	11	65	0.17	[0.09; 0.28]	1.5%
Rathore et al. (2017)	4	11	0.36	[0.11; 0.69]	0.9%
Rathore et al. (2017)	8	39	0.21	[0.09; 0.36]	1.3%
Gallab et al. (2022)	4	20	0.20	[0.06; 0.44]	1.0%
Gallab et al. (2022)	18	30	0.60	[0.41; 0.77]	1.4%
Ramoun et al. (2017)	6	13	0.46	[0.19; 0.75]	1.0%
Ramoun et al. (2017)	12	18	0.67	[0.41; 0.87]	1.1%
Campanile et al. (2007)	44	69	0.64	[0.51; 0.75]	1.6%
Campanile et al. (2013)	47	67	0.70	[0.58; 0.81]	1.6%
Campanile et al. (2013)	47	85	0.55	[0.44; 0.66]	1.7%
Di Francesco et al. (2012)	82	131	0.63	[0.54; 0.71]	1.7%
Di Francesco et al. (2012)	74	125	0.59	[0.50; 0.68]	1.7%
Ghuman et al. (2014)	3	10	0.30	[0.07; 0.65]	0.8%
Gupta et al. (2015)	6	10	0.60	[0.26; 0.88]	0.9%
Gupta et al. (2015)	7	10	0.70	[0.35; 0.93]	0.8%
Gupta et al. (2015)	8	10	0.80	[0.44; 0.97]	0.7%
Gupta et al. (2015)	8	10	0.80	[0.44; 0.97]	0.7%
Gupta et al. (2015)	8	10	0.80	[0.44; 0.97]	0.7%
Hussein et al. (2016)	8	20	0.40	[0.19; 0.64]	1.2%
Karuppanasamy et al. (2017)	3	14	0.21	[0.05; 0.51]	0.9%
Kavita et al. (2018)	10	20	0.50	[0.27; 0.73]	1.2%
Neglia et al. (2008)	96	180	0.53	[0.46; 0.61]	1.8%
Neglia et al. (2016)	67	116	0.58	[0.48; 0.67]	1.7%
Oropeza et al. (2010)	14	40	0.35	[0.21; 0.52]	1.5%
Roy & Parakash (2009)	5	11	0.45	[0.17; 0.77]	1.0%
Roy & Parakash (2009)	6	11	0.55	[0.23; 0.83]	1.0%
Russo et al. (2010)	140	288	0.49	[0.43; 0.55]	1.8%
Sharma et al. (2017)	6	26	0.23	[0.09; 0.44]	1.2%
Overall Effect		3462	0.46	[0.41; 0.52]	65.0%
Heterogeneity: $I^2 = 78\%$, $\tau^2 = 0.4869$, $p < 0.01$					
ProtoCat = LH					
Berber et al. (2001)	97	151	0.64	[0.56; 0.72]	1.8%
De Araujo berber et al. (2002)	97	151	0.64	[0.56; 0.72]	1.8%
Overall Effect		302	0.64	[0.59; 0.69]	3.5%
Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 1.00$					

Figure 5: *The forest plot depicted the manipulation in ovulation synchronization (OVS) protocol synchronization and its effect on pregnancy per AI (PAI) in buffaloes. The reported dataset was extracted from the 51 studies reporting the data of 5,706 buffaloes. The METAPROP procedure analyzed the data in the 'meta' package of the R statistical software (ver. 4.4.1). The forest plot was generated through the forest function. Each black dot having a black horizontal line represents the effect size in proportion and its respective 95% confidence interval (CI). The central red dotted line indicates the overall proportion and point estimates moving left to the central line indicate a decrease in PAI. In contrast, point estimates directed towards the right side represent an increase in PAI. The size of the grey square box reflects the relative weighting of the comparison to the overall effect size estimate, with larger squares representing greater weight. The overall effect size and 95% CI are indicated by the respective diamonds at the bottom, which are adjusted according to the random effects models. Overall, synchronization by using the OVS (ProtCat = G) reported 46% PAI (95% CI = 42 to 50%). The subgroup analyses suggested that manipulation in the OVS protocol affected (P < 0.01) the PAI in buffaloes. Replacing the last GnRH with LH resulted in improved PAI (64%), and replacing with estradiol benzoate (EB) decreased PAI (24%). However, caution should be taken as only a few studies reported the data. Interestingly, the incorporation of equine chorionic gonadotropin (eCG) yielded only 31% PAI and pre-synchronization prior to the start of OVS did not prove beneficial in buffaloes.*

The progesterone (P4) synchronization protocol, which was an accidental discovery in beef cattle, has shown promising results in buffaloes. The estrus response rate using the P4 synchronization protocol was more than 70% (Azawi et al., 2012; Naseer et al., 2013; Amin et al., 2019). We conducted a meta-analysis of the 35 studies where estrus synchronization was performed with P4-based protocols and presented in Figure 6. Over 90% of the studies used intra-vaginal devices for the P4 release in buffaloes. The standard controlled internal drug release (CIDR) protocol, which includes PG at the time of CIDR removal, resulted in acceptable PAI (40%) across the season. Administration of EB or GnRH after 48 to 60 hours after CIDR removal improves PAI to 46%. Both hormones trigger the GnRH pulse regulator mechanism which ultimately cause the LH surge to happen. The administration of GnRH or EB at the time of CIDR insert to promote follicle wave emergence in the TAI CIDR protocols yielded 47 and 44% PAI, respectively. Surprisingly, the incorporation of eCG at the time of CIDR removal to stimulate follicle growth in TAI CIDR protocol where EB or GnRH was administered at CIDR insertion boosts the PAI to 56% in buffaloes. The eCG has been found effective in enhancing the ovulation rate, CL growth, and pregnancy rate and P4 concentration in buffaloes (Carvalho et al., 2012).

The season and cyclicity are important considerations in buffalo for a successful pregnancy in response to the estrus synchronization protocol (Figure 7). When the estrus synchronization was initiated in acyclic buffaloes the PAI was 40% but it went up to 49% when synchronization was applied in cyclic buffaloes (Figure 7A). The low PAI in acyclic buffalo might have occurred due to the absence of the circulating P4 in the blood as lack of hypothalamic priming. Irrespective of the synchronization, the PAI in the low breeding season (LBS) was 40% and during the peak breeding season (PBS) it was 47% (Figure 7B). The poor PAI during the LBS likely attributed to the increased day length, and high environmental stress, compromised GnRH and steroidal hormone secretion which ultimately affect the follicle development, oocyte quality and embryo development (Drost, 2007). Moreover, inseminating buffaloes on detected estrus resulted in lower (40%) PAI as compared with timed artificial insemination (TAI) (49%) (Figure 7C).

3. REPRODUCTIVE BIOTECHNOLOGIES IN BUFFALO

Researchers attempted to improve buffalo reproduction by using assisted reproductive technologies (ARTs). The ART includes a range of processes and techniques such as artificial insemination (AI), estrous synchronization (ES), in-vivo derived (IVD), in-vitro embryo production (IVP), intra-cytoplasmic sperm injection (ICSI), cloning, and semen cryopreservation. Forty-one studies were considered to conduct a meta-analysis of blastocyst rate and pregnancy per ET in buffaloes (Table 3). Cumulatively, the ARTs were used to exploit the genetic potential and dissemination of the superior buffalo genotypes. Collectively, the pregnancy per ET in different countries including India (25%), Philippines (17%), China (19%) and Brazil (21%) has been reported in different published works irrespective of the source of the embryo origin (Figure 9C). Despite the parallel development and adaptation of the ART in cattle and buffalo the success in comparison to cattle is less in buffalo. Perhaps optimization of the ARTs protocol is required in buffalo to achieve feasible application in the field. The historical development of the ARTs in buffaloes has been compiled in the Figure 8.

3.1. In-Vivo Derived Embryo (IVD)

After the introduction of AI in buffalo reproduction (1939), the IVD (MOET) was the most advanced and commendable concept in 1980s, to enhance the buffalo genetics quality (Figure 8). The IVD offered an enormous potential using the nondescript buffaloes as surrogate for the embryos retrieved from the high producing buffaloes. But in buffaloes, the IVD resulted in very low embryo recovery. From a donor buffalo, average number of the embryos retrieved was 1.0 (Drost et al., 1988; Vlakhov et al., 1986), 1.6 (Kandil et al., 2012), 2.0 (Cruz et al., 1991), 2.7 (Misra, 1993; Qin et al., 2012), 4.5 (Kasiraj et al., 1993), and 5.8 (Singh et al., 2015). The procedure for the IVD requires expertise, meet several difficulties, still the embryo retrieval is comparably low as compared to the cattle (Neglia & Bifulco, 2017). The factor influencing the efficiency of the IVD in buffaloes has very well elaborated (Hufana-Duran & Duran, 2015; Neglia & Bifulco, 2017) attributed to the less primordial follicle reserves and fimbriae capacity to capture

oocytes due to high estrogen. Pregnancy per ET is presented in Figure 9D, where embryos originated from IVD, in-vitro embryo production (OPU/IVP), and somatic cell nuclear transfer (SCNT). The pregnancy per ET was higher (31%) in the IVD embryos as compared to IVP (21%) either oocytes obtained from slaughterhouse or ovum pickup, and SCNT (22%). The low recovery rate and technicalities in IVD illustrates the limitation in the adaptation of the embryo transfer technology by the stakeholders and farmers.

Study	Events	Total	Proportion	95%-CI	Weight
ProtoCat = P4					
Feng et al. (1990)	15	61	0.25	[0.14; 0.37]	1.6%
Diaz et al. (1996)	10	15	0.67	[0.38; 0.88]	1.0%
Presicce et al. (2003)	2	10	0.20	[0.03; 0.56]	0.6%
Sathiamoorthy et al. (2007)	7	15	0.47	[0.21; 0.73]	1.0%
Naseer et al. (2011)	11	65	0.17	[0.09; 0.28]	1.5%
Naseer et al. (2011)	6	20	0.30	[0.12; 0.54]	1.1%
Cai et al. (2011)	13	23	0.57	[0.34; 0.77]	1.2%
Naveed et al. (2014)	23	43	0.53	[0.38; 0.69]	1.5%
Yousuf et al. (2015)	19	46	0.41	[0.27; 0.57]	1.6%
Yousuf et al. (2015)	50	106	0.47	[0.37; 0.57]	1.9%
Haider et al. (2015)	5	50	0.10	[0.03; 0.22]	1.1%
Haider et al. (2015)	19	51	0.37	[0.24; 0.52]	1.6%
Haider et al. (2015)	20	50	0.40	[0.26; 0.55]	1.6%
Devipriya et al. (2015)	16	30	0.53	[0.34; 0.72]	1.4%
Amin et al. (2019)	15	25	0.60	[0.39; 0.79]	1.3%
Samir et al. (2019)	9	18	0.50	[0.26; 0.74]	1.1%
Ramoun et al. (2017)	10	20	0.50	[0.27; 0.73]	1.2%
Ghuman et al. (2014)	6	9	0.67	[0.30; 0.93]	0.7%
Hussein et al. (2016)	7	20	0.35	[0.15; 0.59]	1.1%
Overall Effect		677	0.41	[0.33; 0.49]	23.9%
Heterogeneity: $I^2 = 69\%$, $\tau^2 = 0.3472$, $p < 0.01$					
ProtoCat = G.TAI					
RaviKumar et al. (2005)	5	12	0.42	[0.15; 0.72]	0.9%
Alyas et al. (2013)	4	6	0.67	[0.22; 0.96]	0.5%
Kalwar et al. (2015)	9	17	0.53	[0.28; 0.77]	1.1%
Gabriel et al. (2019)	18	50	0.36	[0.23; 0.51]	1.6%
Gabriel et al. (2019)	20	50	0.40	[0.26; 0.55]	1.6%
Gabriel et al. (2019)	18	50	0.36	[0.23; 0.51]	1.6%
De Rensis et al. (2005)	6	20	0.30	[0.12; 0.54]	1.1%
De Rensis et al. (2005)	34	66	0.52	[0.39; 0.64]	1.7%
Samir et al. (2019)	12	18	0.67	[0.41; 0.87]	1.0%
Carvalho et al. (2021)	18	77	0.23	[0.14; 0.34]	1.6%
Carvalho et al. (2021)	50	83	0.60	[0.49; 0.71]	1.8%
Bhat et al. (2015)	19	25	0.76	[0.55; 0.91]	1.1%
Overall Effect		474	0.47	[0.37; 0.56]	15.6%
Heterogeneity: $I^2 = 73\%$, $\tau^2 = 0.3217$, $p < 0.01$					
ProtoCat = EB.eCG.TAI					
Murugavel et al. (2009)	5	11	0.45	[0.17; 0.77]	0.8%
Murugavel et al. (2009)	8	21	0.38	[0.18; 0.62]	1.2%
Khan et al. (2018)	25	44	0.57	[0.41; 0.72]	1.5%
Monterio et al. (2015)	31	48	0.65	[0.49; 0.78]	1.6%
Monterio et al. (2015)	33	47	0.70	[0.55; 0.83]	1.5%
Monterio et al. (2015)	29	47	0.62	[0.46; 0.75]	1.6%
Carvalho et al. (2014)	62	111	0.56	[0.46; 0.65]	1.9%
Carvalho et al. (2014)	67	121	0.55	[0.46; 0.64]	1.9%
Carvalho et al. (2014)	57	118	0.48	[0.39; 0.58]	1.9%
Carvalho et al. (2007)	31	57	0.54	[0.41; 0.68]	1.7%
Carvalho et al. (2007)	33	67	0.49	[0.37; 0.62]	1.7%
Carvalho et al. (2007)	27	55	0.49	[0.35; 0.63]	1.6%
Carvalho et al. (2007)	35	63	0.56	[0.42; 0.68]	1.7%
Monterio et al. (2018)	20	37	0.54	[0.37; 0.71]	1.5%
Monterio et al. (2018)	193	304	0.63	[0.58; 0.69]	2.0%
Overall Effect		1151	0.56	[0.52; 0.60]	24.0%
Heterogeneity: $I^2 = 32\%$, $\tau^2 = 0.0266$, $p = 0.11$					
ProtoCat = EB.TAI					
Murugavel et al. (2009)	5	14	0.36	[0.13; 0.65]	0.9%
Murugavel et al. (2009)	4	19	0.21	[0.06; 0.46]	0.9%
Khan et al. (2018)	13	43	0.30	[0.17; 0.46]	1.5%
Carvalho et al. (2017)	76	168	0.45	[0.38; 0.53]	2.0%
Carvalho et al. (2017)	74	172	0.43	[0.36; 0.51]	2.0%
Carvalho et al. (2017)	85	171	0.50	[0.42; 0.57]	2.0%
Bhat et al. (2015)	21	25	0.84	[0.64; 0.95]	1.0%

Overall Effect		612		0.44 [0.31; 0.58]	10.1%
Heterogeneity: $I^2 = 72\%$, $\tau^2 = 0.4270$, $p < 0.01$					
ProtoCat = EB/G					
Naseer et al. (2011)	10	17		0.59 [0.33; 0.82]	1.1%
Naseer et al. (2011)	11	18		0.61 [0.36; 0.83]	1.1%
Cai et al. (2011)	16	30		0.53 [0.34; 0.72]	1.4%
Cai et al. (2011)	16	40		0.40 [0.25; 0.57]	1.5%
Yousuf et al. (2015)	17	45		0.38 [0.24; 0.53]	1.5%
Yousuf et al. (2015)	55	101		0.54 [0.44; 0.64]	1.8%
Haider et al. (2015)	8	16		0.50 [0.25; 0.75]	1.0%
Haider et al. (2015)	10	17		0.59 [0.33; 0.82]	1.1%
Haider et al. (2015)	3	17		0.18 [0.04; 0.43]	0.8%
Carvalho et al. (2013)	50	129		0.39 [0.30; 0.48]	1.9%
Bhat et al. (2015)	4	10		0.40 [0.12; 0.74]	0.8%
Overall Effect		440		0.46 [0.40; 0.53]	14.0%
Heterogeneity: $I^2 = 40\%$, $\tau^2 = 0.0642$, $p = 0.08$					
ProtoCat = eCG/eCG.G/EB.eCG					
Naveed et al. (2014)	11	45		0.24 [0.13; 0.40]	1.4%
Carvalho et al. (2013)	68	127		0.54 [0.44; 0.62]	1.9%
Barile et al. (2001)	26	40		0.65 [0.48; 0.79]	1.5%
Neglia et al. (2003b)	28	100		0.28 [0.19; 0.38]	1.8%
Neglia et al. (2003b)	5	9		0.56 [0.21; 0.86]	0.7%
Overall Effect		321		0.44 [0.28; 0.61]	7.3%
Heterogeneity: $I^2 = 86\%$, $\tau^2 = 0.5067$, $p < 0.01$					
ProtoCat = Resynch					
Arshad et al. (2017)	26	63		0.41 [0.29; 0.54]	1.7%
Arshad et al. (2017)	28	55		0.51 [0.37; 0.65]	1.6%
Arshad et al. (2017)	40	63		0.63 [0.50; 0.75]	1.7%
Overall Effect		181		0.52 [0.39; 0.64]	5.0%
Heterogeneity: $I^2 = 68\%$, $\tau^2 = 0.1413$, $p = 0.05$					
Overall Effect		3856		0.47 [0.44; 0.51]	100.0%
Heterogeneity: $I^2 = 71\%$, $\tau^2 = 0.2375$, $p < 0.01$					
Test for subgroup differences: $\chi_6^2 = 17.41$, df = 6 ($p < 0.01$)					

Figure 6: The forest plot depicted the manipulation in progesterone (P4) synchronization and its effect on pregnancy per AI (PAI) in buffaloes. The reported dataset was extracted from the 43 studies reporting the data of 3,856 buffaloes. The METAPROP procedure analyzed the data in the 'META' package of the R statistical software (ver. 4.4.1). The forest plot was generated through the forest function. Each black dot having a black horizontal line represents the effect size in proportion and its respective 95% confidence interval (CI). The central red dotted line indicates the overall proportion and point estimates moving left to the central line indicate a decrease in PAI. In contrast, point estimates directed towards the right side represent an increase in PAI. The size of the grey square box reflects the relative weighting of the comparison to the overall effect size estimate, with larger squares representing greater weight. The overall effect size and 95% CI are indicated by the respective diamonds at the bottom, which are adjusted according to the random effects models. Over 90% of the studies used intra-vaginal devices for the P4 release in buffaloes. The standard controlled internal drug release (CIDR) protocol, which includes PG at the time of CIDR removal, resulted in 40% PAI across the season. Administration of EB or GnRH 48 to 60 hours after CIDR removal, improves PAI to 46%. Both hormones trigger the GnRH pulse regulator mechanism, which ultimately causes the LH surge to happen. The administration of GnRH or EB at the time of CIDR insert to promote follicle wave emergence in the TAI CIDR protocols yielded 47 and 44% PAI, respectively. Surprisingly, the incorporation of eCG at the time of CIDR removal to stimulate follicle growth in TAI CIDR protocol where EB or GnRH was administered at CIDR insertion boosts the PAI to 56% in buffaloes.

3.2. In-Vitro Embryo Production (IVP)

Due to poor embryo recovery in IVD, an alternative method to exploit the genetic potential of the high yielding buffalo is IVP where oocytes can be sourced either from ovum pick (OPU) or abattoir (Baruselli et al., 2018; Marin et al., 2019; Ohashi et al., 2022). In buffaloes, the OPU-IVP provide an acceptable model for commercial application where the oocytes source can be traced. However, the limitation is the low number of oocyte retrieval per session that could be attributed to the less follicle reserve, smaller ovarian size and poor stimulation is response to FSH (Danell 1987; Carvalho et al., 2007; Petrovas et al., 2020). Additionally, the seasonality compromised the oocyte competence (di Francesco et al., 2011; 2012). Apart of the sources of the oocytes, the IVP technologies has limited success in the buffalo. The maximum proportion of blastocyst formation is between 14-18% in buffalo rearing countries (Figure 9A). Early work of IVP yield less embryo output likely this technology was copied from the cattle. However, recent data suggest that blastocyst formation in the IVP is improving through the optimized work (Gasparrini et al., 2006; 2008). This can be deduced that there is need to work on the improvement of the IVP technology in buffalo to make it feasible for commercialization.
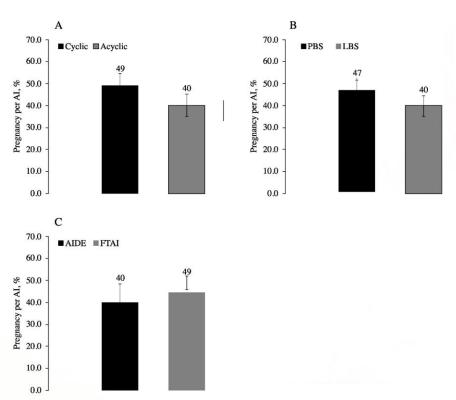
Figure 7: *Association of cyclicity, season, and breeding method with pregnancy per artificial insemination in buffaloes. The bar graphs for each parameter were generated from the forest plot function in the 'meta' package of the R statistical software (ver. 4.4.1). A) The dataset for the cyclicity was extracted from 48 studies reporting the data of 5,554 buffaloes. When the estrus synchronization was initiated in acyclic buffaloes the PAI was 40% but it went up to 49% when synchronization was applied in cyclic buffaloes (P < 0.01). B) The dataset for the season was extracted from 44 studies reporting the data of 6,781 buffaloes. Irrespective of the synchronization, the PAI in the low breeding season (LBS) was 40% and during the peak breeding season (PBS) it was 47% (P = 0.02). C) The dataset for the breeding method was extracted from 72 studies reporting the data of 10,881 buffaloes. Inseminating buffaloes on detected estrus resulted in lower (P = 0.05; 40 vs. 49%) PAI as compared with fixed timed AI (FTAI).*
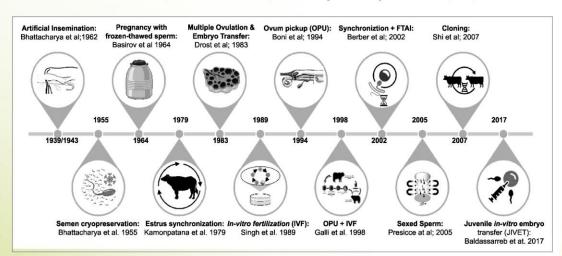
Figure 8: *Historically landmarks achieved in assisted reproductive biotechnology in buffaloes. To improve readability, follow the zig zag pattern. The image is copyright protected, use or reproduce it with author's permission.*

KEYNOTE – BREEDING AND REPRODUCTION
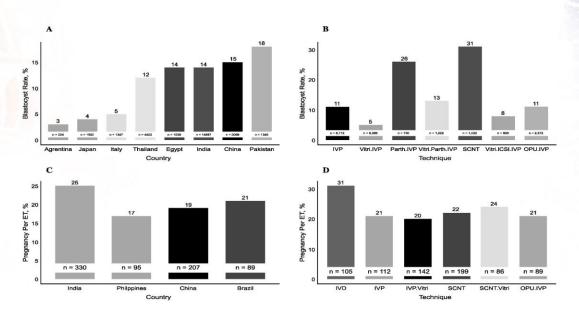
Figure 9: The blastocyst rates and pregnancy per ET by country and techniques in buffaloes. The bar graphs for each parameter were generated from the forest plot function in the 'meta' package of the R statistical software (ver. 4.4.1). A) The dataset for the blastocyst rate by country was extracted from 33 studies reporting the data of 32,665 buffalo oocytes. The maximum proportion of blastocyst formation is between 14-18% in buffalo rearing countries. B) The dataset for the blastocyst rate by technique was similar as for Figure 12A. Surprisingly, blastocyst rate was higher (31%) by somatic cell nuclear transfer (SCNT), following by parthenogenesis (26%), in-vitro embryo production-IVP (11%), and intra-cytoplasmic sperm injected-ICSI (8%) embryos. C) The dataset for the pregnancy per ET by country was extracted from 18 studies reporting the data of 733 buffalo recipients. Collectively, the pregnancy per ET in different countries including India (25%), Philippines (17%), China (19%) and Brazil (21%) has reported in different published work irrespective of the source of the embryo origin. D) The dataset for the pregnancy per ET by technique was extracted from 18 studies reporting the data of 733 buffalo recipients. Embryos originated from in-vivo derived (IVD), in-vitro embryo production (IVP), and somatic cell nuclear transfer (SCNT). The pregnancy per ET was higher (31%) in the IVD embryos as compared to IVP (21%) either oocytes obtained from slaughterhouse or ovum pickup (OPU) and SCNT (22%). Abbreviations: Vitri, vitrification; Parth, parthenogenesis.

3.3. Cloning

In 1999, the first cloned embryo was successfully produced in swamp buffalo by somatic cell nuclear transfer (SCNT) using fetal fibroblasts (Parnpai et al., 1999). In 2004, three recipients were pregnant with cloned swamp buffalo embryos originating from fetal fibroblasts, but all recipients aborted before the term (Saikhun et al., 2004). A similar experiment was also performed on riverine buffalo, transferring cloned embryos derived from fetal fibroblasts, but no recipient conceived (Simon et al., 2006). The first successful SCNT calf was born in 2007 using granulosa cells in swamp buffalo (Shi et al., 2007) (Figure 8). In supersession to this, multiple cloned riverine and swamp calves were produced either by conventional SCNT (Wilmut et al., 1997) or handmade cloning (Vajta, 2007). Surprisingly, blastocyst rate was higher (31%) by SCNT, following by parthenogenesis (26%), IVP (11%) and intra-cytoplasmic sperm injected (8%) embryos (Figure 9B). Recently elite genetics buffalo bulls were produced by cloning (Selokar, 2018; Selokar et al., 2019). Interestingly, the semen of cloned buffalo bulls is commercialized in India.

3.4. Sexed semen

Many studies have been documented on the history, development and application of the sexed semen technology in livestock production, including buffaloes (Vishwanath & Moreno, 2018; Presicce, 2022; Yata, 2022). The first pregnancy achieved through sex semen was reported in buffaloes by researchers from Italy (Presicce et al., 2005). They reported 43% of pregnancies by using the X or Y-sorted sperms, which was similar to the pregnancy reported by using the frozen-thawed buffalo semen. A higher pregnancy rate was achieved when semen was deposited in the uterus as compared to the uterine horn (Campanile et al., 2011). Sexed semen has been successfully incorporated into the IVD or IVP for production of commercial-level sexed embryo production (Liang et al., 2008; Lu et al., 2010; Presicce, 2022). The pregnancy rate with IVD

embryos produced by using sexed semen was reported to be similar (49.3% vs 45.2%) to conventional buffalo semen (Campanile et al., 2011; 2013). The fertilizing ability of sperm following the sex-sorting varies among the buffalo bulls (Lu et al., 2010). To enhance buffalo production, further studies are required to adopt and evaluate the impact of sex-sorting technology (Lu et al., 2015). We foresee that the application of this technology through private company will grow, utilizing sexed semen and sexed embryos. high estrogen. Pregnancy per ET is presented in Figure 9D, where embryos originated from IVD, in-vitro embryo production (OPU/IVP), and somatic cell nuclear transfer (SCNT). The pregnancy per ET was higher (31%) in the IVD embryos as compared to IVP (21%) either oocytes obtained from slaughterhouse or ovum pickup, and SCNT (22%). The low recovery rate and technicalities in IVD illustrates the limitation in the adaptation of the embryo transfer technology by the stakeholders and farmers.

Recommendations for buffalo females

1. Puberty in buffaloes can be achieved within 24 months by providing better nutrition and management.

2. The pregnancy with the natural breeding is not higher than 60% in buffaloes. Likely because of higher pregnancy loss which require intensive research on luteal insufficiency, oviduct, and uterine environment in buffalo.

3. Pregnancy per AI of 53% can be achieved with single insemination by AM-AM role and must be promoted.

4. The emerging technology such as CRISPR-Cas9 must be explored to address the challenges in the area of estrus behavior (standing estrus), and seasonality in the buffalo.

5. Use of precision livestock technology (i.e., Cow-Collar or ultrasound) to improve reproductive efficiency of buffalo must be encouraged.

6. The synchronization is possible in buffaloes, the PAI through single PG, OVS and standard CIDR protocol is 37 to 46%. By incorporation of hormones in the CIDR protocol for wave emergence, follicle growth and timed insemination improves (56%) pregnancy per AI. However, the cost to benefit ratio need to be assessed while using the multiple hormones in the CIDR protocol. Timed AI is new tool with acceptable PAI needs to be encouraged on commercial level.

7. Transition period management, especially energy balance and health, should be prioritized in buffaloes.

8. Season, and cyclicity are important parameters that influence the PAI in buffaloes. More research requires in the area.

9. The reproductive biotechnology (i.e., OPU-IVP, vitrification, sexed semen or cloning) are possible in buffalo, however for commercialization, improvements in the techniques are required.

10. The adaptability of the reproductive biotechnology to improve reproduction can be enhanced by creating awareness among stakeholders and choosing the suitable business model for the end users.

11. International collaboration should be strengthened by establishing CART-center for assisted reproductive biotechnology.

12. Academia, private and livestock department linkage are keys to the success of buffalo breeding and production.
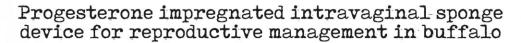
Conclusion

The quantity and quality of the breeding bulls in the progeny testing program along with lack of incentive based program for breeders are the major hindrance for the breed improvement. The growth and reproductive standards for the breeding bulls have been comprehensively developed. Numerous research works have been published in buffalo semen processing and cryopreservation for improved post-thawed quality and leading to commercialization. Despite this intensive work, the adoption of artificial insemination (AI) in buffalo remained low. In buffalo heifers, puberty can be achieved within 24 months by providing better nutrition and management. Surprisingly, pregnancy with natural breeding is not greater than 60% in buffalo. Seasonality affects the PAI by 10% point which is lower in the LBS than the PBS. By adopting the AM-AM rule, 53% PAI is achievable with single insemination in spontaneous estrus. Estrus synchronization protocols work in buffalo and PAI can be improved by controlling follicle wave emergence, promoting follicle growth, and ovulation induction. To achieve sustainable developmental goals for food security, the ARTs must be optimized, and commercialized in buffalo rearing countries.

N.B. For complete list of reference please follow this link -
https://drive.google.com/file/d/1vqfw6H1wodcLpNI-E7tqyVOw0-qSTAea/view?pli=1

Progesterone impregnated intravaginal sponge device for reproductive management in buffalo

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Abstract

Whole genome sequencing has revolutionized livestock genomics, enhancing the preservation of genetic traits in landraces vital to specific agro-climatic regions. Asia, especially in India, hosts some of the oldest and most agriculturally significant buffalo populations. Among India's diverse buffalo breeds, the Murrah stands out for its substantial milk productivity, being the best dairy breed globally. This study focused on the whole genome sequencing of Murrah buffalo bull sires to identify SNPs and INDELs, and to perform gene annotation and sequence ontology using. Blood samples from Murrah buffalo bulls (aged 4 to 10) were collected at the Artificial Breeding Research Center, ICAR-National Dairy Research Institute in Karnal, India. Genomic DNA was isolated and sequenced using Illumina NovaSeq 6000 technology, producing 150-bp paired-end reads. The resulting FASTQ files were trimmed and aligned against the water buffalo assembly (UOA_WB1) using BWA-MEM2. Post-alignment, the GATK pipeline was employed for BAM file deduplication and VCF calling with HaplotypeCaller. The gene annotation and sequence ontology was performed using SnpEff & SnpSift respectively. The results indicated post trimming alignment percentage ranging from 67.43% to 76.33% across the 25 nuclear chromosomes and the mitochondrial genome. Depth of coverage for autosomal chromosomes varied from 8.8X to 22.15X, while mitochondrial genome depth ranged from 8.85X to 1405.06X. Pre-filtration, there were 34,006,357 SNPs, identified which reduced to 30,183,378 post-filtration based on specific criteria. For INDELs, 4,819,890 were reduced to 4,769,590 after filtration. Mitochondrial variants ranged from 5101 to 681. SNPs were more prevalent than INDELs, with C>T and G>A substitutions being the most common. The data generated will be useful in identifying the polymorphism potentially associated with semen quality and other reproduction traits in buffalo bulls.

Keywords: Water Buffalo, Murrah, breeding bulls, whole genome sequencing, sequence ontology.

Interferon-tau and pregnancy-associated glycoproteins as early markers of pregnancy in buffalo

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Abstract

The success of a pregnancy depends on a series of complex biological processes and several key points, including adequate communication between the mother and the embryo to create a uterine environment that ensures the implantation and survival of the embryo. One of the first molecules involved in the complex mechanism of maternal recognition of pregnancy is the interferon-tau (IFNt), secreted by the mononucleate Regarding IFNt, it is possible to detect the protein in the blood from day 14 post-AI. Animals that experienced embryo mortality showed lower IFNt values than pregnant animals, showing that the production of appropriate levels of IFNt is necessary for the embryos' survival. Despite the significant difference in the IFNt levels between pregnant and non-pregnant buffaloes, a great individual variability was found, therefore, unlike PAGs, it cannot be utilised as a reliable marker of pregnancy.
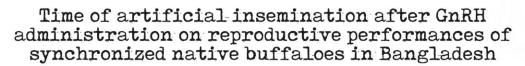
Keywords: Interferon tau, pregnancy-associated glycoproteins, pregnancy.

ORAL PRESENTATION

Time of artificial insemination after GnRH administration on reproductive performances of synchronized native buffaloes in Bangladesh

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Abstract

The aim of the study was to increase the reproductive efficiencies of native buffaloes using estrus synchronization technique. The buffalo cows (n=42) of second to fifth parity with good body condition score were selected for estrus synchronization at Madarganj, Jamalapur and Companiganj, Noakhali. Buffaloes were synchronized with Ovsynch protocol. In this protocol, buffaloes were injected 5 ml Gonadorelin (GnRH) (50 mcg; ACI Limited, Dhaka) on day 0, 5 ml Dinoprost (PGF2α), KP (5 mg; ACI Limited) on day 7 and the second Gonadorelin injection was given on day 9, and artificial insemination (AI) was performed with frozen semen prepared by Bangladesh Livestock Research Institute (BLRI) at either 16 (group 1; n=13), 20 (group 2; n=21) or 24 hours(group 3; n=8) after final dose of Gonadorelin injection. The results showed that all buffaloes showed estrus in group 3 which was higher than group 2 (91.67%) and group 1 (88.89%) but the values did not differ significantly (p>0.05). The conception rate was 83.33% in group 1, higher (p>0.05)than group 2 and group 3. On the other hand, the calving rate (66.67%) was significantly (P<0.05) higher in the buffaloes inseminated16 hours after the second dose of GnRH administration than the buffaloes inseminated 24 hours after thesecond dose of GnRH administration.The results revealed that artificial insemination at 16 hours after the second dose of GnRH administration significantly (p<0.05) increased calving rate of synchronized native buffaloes. Thus, artificial insemination at 16 hours after the second dose of GnRH administration increases the reproductive performances of synchronizednative buffaloes in Bangladesh.

Keywords: Calving rate, conception, estrus synchronization, ovsynch protocol.

Developmental competence and molecular signatures of cloned and recloned embryos derived from (non-) transgenic cloned buffalos
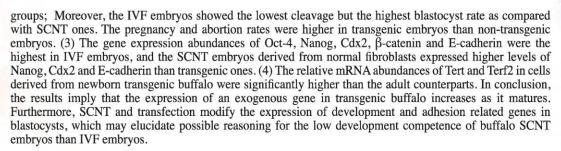
Chun-Yan Yang[1,2]*, Hai-Ying Zheng[1,2], Guang-sheng Qin[1,2], Pan Li[2], Zheng-zhunTan[1,2], JianHuang[1,2] and Jiang-Hua Shang[1,2]*

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Abstract

This study was performed to investigate the developmental competence of SCNT embryos derived from transfected cells and transgenic cloned buffalos, and to investigate if the expression intensity of exogenous gene varies with the growth of transgenic buffalo. A transgenic cloned buffalo carrying enhanced green fluorescent protein (EGFP) gene was obtained, and the cells derived from this transgenic buffalo at different ages were adopted for re-cloning. Developmental competence and expression levels of key genes for developmental potential and telomere (Oct-4, Sox2, Nanog, Cdx2, Gata3, E-cadherin, β-catenin, Tert, Terc, Terf1 and Terf2) were explored in SCNT embryos and cells. The results showed that (1) the expression of EGFP in the transgenic buffalo increased with buffalo age (P<0.01). Furthermore, the first calf of the transgenic buffalo did not express EGFP, while the second one did. (2) The fusion and cleavage rates of reconstructed embryos derived from different lines of cells (normal fibroblasts, fibroblasts of cloned buffalo, transfected fibroblasts, fibroblasts of the new-born and adult transgenic cloned buffalo) were not significantly different from each other, while the blastocyst rate of SCNT embryos in transfected fibroblasts group was relatively higher than the other SCNT

ORAL PRESENTATION

groups; Moreover, the IVF embryos showed the lowest cleavage but the highest blastocyst rate as compared with SCNT ones. The pregnancy and abortion rates were higher in transgenic embryos than non-transgenic embryos. (3) The gene expression abundances of Oct-4, Nanog, Cdx2, β-catenin and E-cadherin were the highest in IVF embryos, and the SCNT embryos derived from normal fibroblasts expressed higher levels of Nanog, Cdx2 and E-cadherin than transgenic ones. (4) The relative mRNA abundances of Tert and Terf2 in cells derived from newborn transgenic buffalo were significantly higher than the adult counterparts. In conclusion, the results imply that the expression of an exogenous gene in transgenic buffalo increases as it matures. Furthermore, SCNT and transfection modify the expression of development and adhesion related genes in blastocysts, which may elucidate possible reasoning for the low development competence of buffalo SCNT embryos than IVF embryos.

Keywords: Transgenic buffalo, re-cloning, EGFP, developmental competence, telomere.

Genetic parameters for growth traits in Thai Swamp buffaloes

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Abstract

The Thai swamp buffalo (Bubalus bubalis carabanesis) is vital to Thai agriculture and the rural economy, providing labor, meat, milk, hides, and dung. Despite their importance, productivity and quality have been suboptimal due to inadequate genetic improvement efforts. This study aims to estimate genetic parameters for key growth traits to support effective breeding programs. Body size and weight data were collected from 1,652 buffaloes born between 2013 and 2022 across 42 farms in six provinces. Variance components were estimated using an average-information restricted maximum likelihood procedure, and a multiple-traits animal model was applied to produce the best linear unbiased predictions of genetic abilities and estimate genetic correlations. Heritability estimates for weight at birth, 240, 400, 600, and 720 days were 0.69 ± 0.03, 0.46 ± 0.03, 0.33 ± 0.02, 0.37 ± 0.03, and 0.08 ± 0.01, respectively. Genetic correlations were generally positive, except for a negative correlation between weights at 240 and 720 days (-0.10). These results indicate substantial genetic influence on growth traits, highlighting areas for effective selective breeding. Utilizing these genetic parameters, breeding programs can more accurately select for desirable traits, enhancing growth rates and productivity.

Keywords: Swamp buffalo, genetic parameters, heritability, breeding, growth traits.

Oestrus detection based on accelerometer monitoring system in buffalo cows: preliminary results

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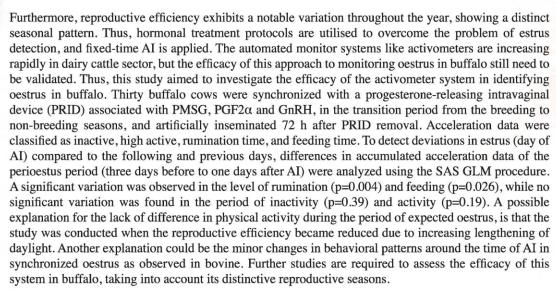
Abstract

It is crucial to correctly identify animals in oestrus, to estimate the optimal time for artificial insemination (AI). Oestrus behaviour in buffalo is difficult to detect due to the lack of pronounced oestrus signs.

Furthermore, reproductive efficiency exhibits a notable variation throughout the year, showing a distinct seasonal pattern. Thus, hormonal treatment protocols are utilised to overcome the problem of estrus detection, and fixed-time AI is applied. The automated monitor systems like activometers are increasing rapidly in dairy cattle sector, but the efficacy of this approach to monitoring oestrus in buffalo still need to be validated. Thus, this study aimed to investigate the efficacy of the activometer system in identifying oestrus in buffalo. Thirty buffalo cows were synchronized with a progesterone-releasing intravaginal device (PRID) associated with PMSG, PGF2α and GnRH, in the transition period from the breeding to non-breeding seasons, and artificially inseminated 72 h after PRID removal. Acceleration data were classified as inactive, high active, rumination time, and feeding time. To detect deviations in estrus (day of AI) compared to the following and previous days, differences in accumulated acceleration data of the perioestus period (three days before to one days after AI) were analyzed using the SAS GLM procedure. A significant variation was observed in the level of rumination (p=0.004) and feeding (p=0.026), while no significant variation was found in the period of inactivity (p=0.39) and activity (p=0.19). A possible explanation for the lack of difference in physical activity during the period of expected oestrus, is that the study was conducted when the reproductive efficiency became reduced due to increasing lengthening of daylight. Another explanation could be the minor changes in behavioral patterns around the time of AI in synchronized oestrus as observed in bovine. Further studies are required to assess the efficacy of this system in buffalo, taking into account its distinctive reproductive seasons.

Keywords: Oestrus detection, activometer, automated systems.

Strategic crossbreeding to enhance milk yield for sustainable buffalo production in Bangladesh

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Abstract

This study was carried out to know the impact of crossbreeding Italian Mediterranean buffaloes with local breeds on milk yield in Bangladesh. Daily milk production data were collected from 50 lactations of 23 buffalo cows from three genotypes (Local, Murrah dominated cross and graded F1 Mediterranean cross) during 2014 to 2023 at the research farm of Lal Teer Livestock Development (BD) Limited (LTLDB), Mymensingh. In addition, a survey was conducted from 46 buffalo farmers to clarify the ongoing milk price and major economic benefits of buffalo rearing. Data analysis were performed by One-way ANOVA following Completely Randomized Design (CRD) including descriptive statistics and Tukey's HSD post-hoc mean separation tests. Results showed no significant differences (p>0.05) in calving interval and lactation length among the breeds but differed in lactation yield (p<0.001). The average lactation yield and lactation periods were 525.60±76.76 kg and 264.35±10.08 days for Local buffaloes, 793.08±99.10 kg and 270.58±13.01 days for Murrah cross buffaloes, and 1123.67±80.92 kg and 268.61±10.61 days for F1 Mediterranean cross buffaloes, respectively. Variations in milk yield across lactation stages were significant (p<0.001), with Mediterranean cross buffaloes maintaining superior yield throughout early (4.22±0.32 kg/day), mid (4.47±0.30 kg/day), and late (3.53±0.24 kg/day) lactations. The F1-crossed buffalo attained sexual maturity earlier (31.23±1.08 months) than local female (42.52±2.79 months) buffalo populations (p<0.0001) which may be advantageous for lifetime calf productions. Buffalo milk price ranged from 73-133 BDT/Kg giving top priority for higher price in raw milk or milk products price (30%). These findings highlight the genetic potential of Mediterranean cross buffaloes to enhance milk production in sustainable manner.

Keywords: Crossbreeding, milk yield, buffalo breeds, lactation stages, genetic potential.

ORAL PRESENTATION

Genome-wide polymorphism analysis of Murrah buffalo breeding bulls

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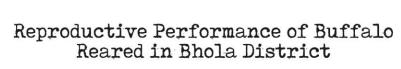
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Abstract

Whole genome sequencing has revolutionized livestock genomics, enhancing the preservation of genetic traits in landraces vital to specific agro-climatic regions. Asia, especially India, hosts some of the oldest and most agriculturally significant buffalo populations. Among India's diverse buffalo breeds, the Murrah stands out for its substantial milk productivity, being the best dairy breed globally. This study focused on the whole genome sequencing of Murrah buffalo bull sires to identify SNPs and INDELs, and to perform gene annotation and sequence ontology using. Blood samples from Murrah buffalo bulls (aged 4 to 10) were collected at the Artificial Breeding Research Center, ICAR-National Dairy Research Institute in Karnal, India. Genomic DNA was isolated and sequenced using Illumina NovaSeq 6000 technology, producing 150-bp paired-end reads. The resulting FASTQ files were trimmed and aligned against the water buffalo assembly (UOA_WB1) using BWA-MEM2. Post-alignment, the GATK pipeline was employed for BAM file deduplication and VCF calling with HaplotypeCaller. The gene annotation and sequence ontology was performed using SnpEff & SnpSift respectively. The results indicated post trimming alignment percentage ranging from 67.43% to 76.33% across the 25 nuclear chromosomes and the mitochondrial genome. Depth of coverage for autosomal chromosomes varied from 8.8X to 22.15X, while mitochondrial genome depth ranged from 8.85X to 1405.06X. Pre-filtration, there were 34,006,357 SNPs, identified which reduced to 30,183,378 post-filtration based on specific criteria. For INDELs, 4,819,890 were reduced to 4,769,590 after filtration. Mitochondrial variants ranged from 5101 to 681. SNPs were more prevalent than INDELs, with C>T and G>A substitutions being the most common. The data generated will be useful in identifying the polymorphism potentially associated with semen quality and other reproduction traits in buffalo bulls.

Keywords: Water Buffalo, Murrah, breeding bulls, whole genome sequencing, sequence ontology.

ORAL PRESENTATION

Reproductive Performance of Buffalo Reared in Bhola District

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Abstract

This study focused on assessing the reproductive performance of indigenous buffaloes raised under subsistence farming in five sub-districts of the Bhola district of Bangladesh. Poor reproductive performance hinders the increase in buffalo production, indicating a direct link between profitability and reproductive efficiency. Data were collected through interviews with 309 randomly selected farmers using pre-tested questionnaires to evaluate various buffalo reproductive parameters. The five sub-districts were Burhanuddin, Lalmohon, Char Fasson, Bhola Sadar, and Tazumuddin. The study revealed that approximately 85% of farmers reared buffaloes in bathan, while the remainder kept them in household settings. The study found that reproductive traits such as age at sexual maturity (years), age at first calving (years), postpartum heat period (days), service per conception (no.), calving interval (months), and gestation period (days) in bathan were (3.09±0.30), (4.06±0.30), (65.05±20.94), (2.01±1.13), (13.76±1.72), and (299.96±6.72), respectively; compared to (3.03±0.22), (4.04±0.20), (63.02±20.80), (1.89±0.67), (14.56±1.75), and (300.31±4.18), respectively in household. Only the service per conception showed a significant difference (p<0.05) between buffaloes reared in bathan and household environments in Bhola district. However, all the reproductive parameters differed significantly (p<0.05) among the five different sub-districts. Age at sexual maturity (years) and postpartum heat period (days) were significantly lower (p<0.05) in Lalmohon, at (2.98±0.08) and (57.1±13.62), respectively, while the calving interval (months) and gestation period (days) were significantly lower (p<0.05) in Bhola Sadar, at (11.92±0.43) and (297.10±6.97), respectively. Data also reveal that service per conception (no.) was lowest (1.46±0.50) in Burhanuddin. Based on the results, it can be concluded that Indigenous buffaloes in Bhola Sadar outperformed those in the other four sub-districts. Additionally, considering the advantageous numerical values of the reported attributes and significantly better service per conception, buffaloes raised in households exhibited superior reproductive characteristics compared to those reared in bathan.

Keywords: Bhola district, indigenous buffalo, reproductive traits.

Frozen semen production performance of Murrah buffalo bulls in Bangladesh

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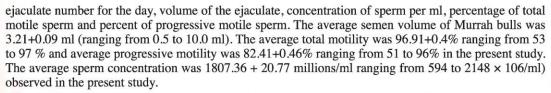
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Abstract

A study was conducted to evaluate semen output characteristics of 342 ejaculates of 3 Murrah buffalo bulls maintained at the Buffalo Breeding and Development Farm, Savar, Dhaka, Bangladesh. The objective of this study was to estimate expected frozen semen dose production. Semen collection was done once in a week and two ejaculations were considered at an interval of 30 minutes from 2019 to 2024. Age of bulls at collection during the study period ranged from 2.5 to 7.0 years. Bulls not donating semen were excluded from the data set. The bulls which gave freezable quality semen for at least six months were considered in the present study. Information collected on each ejaculate included date of collection,

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ejaculate number for the day, volume of the ejaculate, concentration of sperm per ml, percentage of total motile sperm and percent of progressive motile sperm. The average semen volume of Murrah bulls was 3.21+0.09 ml (ranging from 0.5 to 10.0 ml). The average total motility was 96.91+0.4% ranging from 53 to 97 % and average progressive motility was 82.41+0.46% ranging from 51 to 96% in the present study. The average sperm concentration was $1807.36 + 20.77$ millions/ml ranging from 594 to 2148×106/ml) observed in the present study.

The average dilution rate was found to be 10.06+0.13, with a range of 6.25 to 13.67. The expected number of ejaculates that could be frozen per year per bull was 66.29 (ranging from 29 to 100) and correspondingly, the expected frozen doses produced per year per bull could be 7609.29 (ranged 4205 to 11662). The semen quality and the expected frozen doses of semen produced per year per Murrah bull were quite satisfactory in environmental condition of Bangladesh.

Keywords: Murrah, semen quality, expected no. of ejaculate, frozen dose produced.

Estimation of heritability and breeding values in the growth traits of local and F1 crossbreed buffaloes

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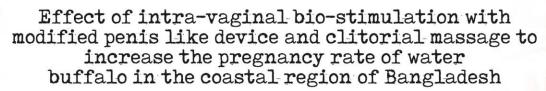
Abstract

The heritability and breeding value estimation for buffalo population are essential for economic importance and predicting superior individuals based on specific traits for which the study was conducted. Data of growth traits were collected from 33 Local/Indigenous and 35 F1 crossbreed (Local × Mediterranean) buffalo progenies. The heritability and breeding values were calculated following the single trait animal model of Restricted Maximum Likelihood (REML) procedure incorporating both fixed (parity, sex, birth season, year of birth and breeding system) and random (animal's additive genetic) effects. The heritability estimates for body weight (BW) in Local buffalo showed comparatively stable ranged from 0.32±0.08 to 0.39±0.07, while for crossbred buffaloes the differences were higher (0.21±0.17 to 0.42±0.11). Average body weights were consistently higher in F1 crossed buffaloes across all age periods (BW0: 35.06±0.82 kg to BW12: 219.70±6.36 kg) indicating a potential benefit of crossbreeding. Similarly, F1 crossed buffaloes exhibit higher average daily gain (ADG) across all periods notably from birth (ADG0: 0.50±0.21) to three (ADG3: 0.37±0.15) months. The estimated breeding values (EBVs) for BW and ADG traits in local and F1 crossed buffaloes revealed significant genetic variability. Interestingly, the twelve-month BW EBVs of Local buffalo progeny ranged from -31 kg to +40 kg, with ADG0-12 from -86 g/d to +115 g/d, while these values found -19 kg to +31 kg, with ADG0-12 EBVs ranging from -55 g/d to +87 g/d in F1 crossed buffalo progenies. Moderate to high heritability estimation suggest that selective breeding can effectively improve body weight in both populations with efficient growth. However, the variability of EBVs indicate individual genetic merits for screening to maximize genetic gains in herd controlling the climatic adverse situations.

Keywords: Body weight, genetic parameters, growth rate, native, synchronization.

Effect of intra-vaginal bio-stimulation with modified penis like device and clitorial massage to increase the pregnancy rate of water buffalo in the coastal region of Bangladesh

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Abstract

This study aimed to determine the effect of intra-vaginal bio-stimulation with a modified penis-like device (mPLD) and clitorial massage subsequent artificial insemination (AI) to increase the pregnancy rate of water buffaloes. The study was conducted from July 2023 to June 2024 in the selected coastal region of Bangladesh. The AI was performed in 160 buffalo cows after observing their estrous sign. During AI, the buffalo cows were divided into four groups (group A: only AI was conducted; group B: intra-vaginal bio-stimulation with mPLD following AI; group C: massage of the clitoris after AI; group D: both mPLD and the clitorial massage was done following AI). Each group consisted of 40 animals. Age, breed, parity, body condition score, reproductive health status, and previous calving difficulties were recorded at AI. The average pregnancy rate was found 41.3%. The pregnancy rate in groups A, B, C, and D were 32.5, 42.2, 37.5 and 52.5%, respectively. It is determined that both application of intra-vaginal bio-stimulation with mPLD and massage of the clitoris following AI (group D) showed a significant ($P<0.05$) effect on pregnancy rate than the control group (group A). The pregnancy rates were influenced ($P<0.05$) by the parity, reproductive health, and previous records of calving difficulties of buffalo cows. The age between 2.5 to 3.5 was found to significantly ($P<0.05$) lower chances of pregnancy than that of other age groups. The age is highly correlated ($P<0.01$ with breed and parity. It is concluded that the application of mPLD in conjugation with massage of the clitoris enhances the pregnancy rate of buffalo cows.

Keywords: Bio-stimulation, clitorial massage, pregnancy rate, artificial insemination.

Season of birth influence age at puberty of Murrah×Indigenous crossbred buffalo heifer
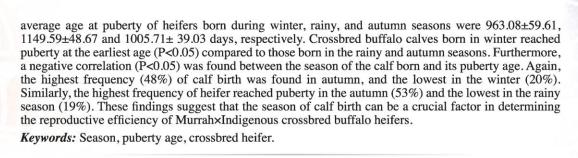
Gautam Kumar Deb[1,2]*, Khadija-Tut-Tahira[1], Md. Ashadul Alam[2], Mst. Parvin Mostari[3], Md. Kamrul Hasan Majumder[2], Imtiaz Ahmed[2] and Sheikh Mohammad Jahangir Hossain[4]

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Abstract

Buffalo rearing is getting increasing interest for its unique attribution in the supply of meat and milk. The profitability of a buffalo farm is dependent on its reproductive efficiency. Age at puberty is associated with lifetime calf as well as milk production. The puberty age is affected by farm management practices in most cases. The present study aimed to evaluate the effect of birth seasons on subsequent age at puberty of Murrah×Indigenous crossbred buffalo heifers. The study was conducted with 59 Murrah×Indigenous crossbred buffalo heifers born at BLRI Buffalo Research Farm, Savar, Dhaka from 2018 to 2023. Calves born during the winter (December to February), rainy (June to August), and autumn (September to November) seasons were included in this study. Age at puberty was estimated when the heifer showed her first heat. Data were analyzed by one-way ANOVA using SPSS 20.00 program. Results showed that the

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average age at puberty of heifers born during winter, rainy, and autumn seasons were 963.08±59.61, 1149.59±48.67 and 1005.71± 39.03 days, respectively. Crossbred buffalo calves born in winter reached puberty at the earliest age (P<0.05) compared to those born in the rainy and autumn seasons. Furthermore, a negative correlation (P<0.05) was found between the season of the calf born and its puberty age. Again, the highest frequency (48%) of calf birth was found in autumn, and the lowest in the winter (20%). Similarly, the highest frequency of heifer reached puberty in the autumn (53%) and the lowest in the rainy season (19%). These findings suggest that the season of calf birth can be a crucial factor in determining the reproductive efficiency of Murrah×Indigenous crossbred buffalo heifers.

Keywords: Season, puberty age, crossbred heifer.

Non-genetic factors influence buffalo milk yield and composition at on-farm

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Abstract

Milk price is generally determined by its fat and protein content. However, they are not emphasized in the genetic improvement programme of buffaloes. This study aimed to determine the effects of non-genetic factors (regions, lactation orders, seasons of calving, sex of calf, and stages of lactation) on buffalo milk yield and composition. This research was conducted in five upazilas (Madargonj, Iswardi, Lalmonirhat, Ramgati and Bauphal) of Bangladesh. The 300-day lactation milk yield (LMY) was estimated following ICAR guidelines and milk compositions were analyzed by a Lactoscan Milk analyzer (Farm Eco, Bulgaria). For this purpose, according to ICAR defined days interval total 1153 test-day milk yield records were collected from 113 buffalo cows. The data were analyzed following GLM. The findings demonstrated the average LMY was 816.39±18.1kg (664.02±24.03kg to 1027.07±22.25kg). Additionally, the average fat, protein, lactose and SNF contents were 8.22±0.05%, 3.68±0.02%, 5.13±0.02%, and 9.69±0.03%, respectively. Therefore, the LMY was affected (P<0.001) by regions, lactation orders (P<0.001), sex of calf (P<0.05) and seasons of calving (P<0.01). Accordingly, fat, protein, lactose and SNF content also differed (P<0.05 to P<0.001) by regions, lactation orders, sex of calf, seasons of calving and stages of lactation. The highest milk fat was found in the 3rd lactation (8.56±0.08%) while the highest milk protein in the 4th lactation (3.87±0.03%). Dam with male calves also had more LMY, protein, and SNF. Moreover, Milk fat content had a positive correlation with the lactation stage but negatively correlated with other factors (P<0.05). Similarly, protein and lactose positively correlated with regions, lactation orders, and calving seasons but negatively related with the sex of calf and lactation stages. In conclusion, it was revealed that milk yield and composition were influenced by different non-genetic factors in buffalo cows.

Keywords: Indigenous buffalo cow, non-genetic factor, milk composition, genomic selection.

Murrah buffalo is a seasonal breeder

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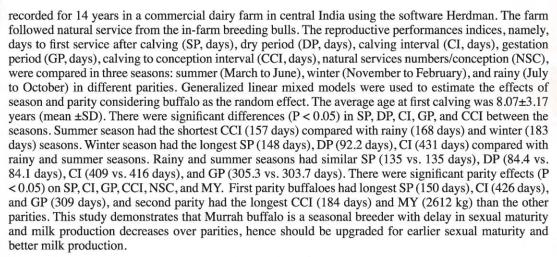
Abstract

Retrospective data of Murrah buffaloes (n = 5816) in parities 1-10, were analyzed to investigate the seasonal influence on reproductive performances and total milk yield/year (MY). Data were digitally

recorded for 14 years in a commercial dairy farm in central India using the software Herdman. The farm followed natural service from the in-farm breeding bulls. The reproductive performances indices, namely, days to first service after calving (SP, days), dry period (DP, days), calving interval (CI, days), gestation period (GP, days), calving to conception interval (CCI, days), natural services numbers/conception (NSC), were compared in three seasons: summer (March to June), winter (November to February), and rainy (July to October) in different parities. Generalized linear mixed models were used to estimate the effects of season and parity considering buffalo as the random effect. The average age at first calving was 8.07±3.17 years (mean ±SD). There were significant differences (P < 0.05) in SP, DP, CI, GP, and CCI between the seasons. Summer season had the shortest CCI (157 days) compared with rainy (168 days) and winter (183 days) seasons. Winter season had the longest SP (148 days), DP (92.2 days), CI (431 days) compared with rainy and summer seasons. Rainy and summer seasons had similar SP (135 vs. 135 days), DP (84.4 vs. 84.1 days), CI (409 vs. 416 days), and GP (305.3 vs. 303.7 days). There were significant parity effects (P < 0.05) on SP, CI, GP, CCI, NSC, and MY. First parity buffaloes had longest SP (150 days), CI (426 days), and GP (309 days), and second parity had the longest CCI (184 days) and MY (2612 kg) than the other parities. This study demonstrates that Murrah buffalo is a seasonal breeder with delay in sexual maturity and milk production decreases over parities, hence should be upgraded for earlier sexual maturity and better milk production.

Keywords: Murrah, season, reproductive indices, milk yield.

Fertility response in post-partum anestrus buffaloes using hormonal protocol vitamin and mineral supplements under field condition in Eastern region of Nepal

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Abstract

This study was conducted to observe the fertility response in post-partum anestrus buffaloes using hormonal protocol, vitamin and mineral supplements under field condition in Eastern region of Nepal. Buffaloes (n=56) were allocated into 3 groups based of body condition score (BCS) and ovarian status per-rectum examination; G1 [n=17; BCS (poor), ovaries (quiescent, smooth, small and irregular in size)]; G2 [n=21; BCS (good), ovaries (lively, rough and normal in size) and G3 [n=18; BCS (average), ovaries (average structure in size]. The G1 and G2 were treated using hormonal protocols; GnRH-PGF2α- GnRH and CIDR- PGF2α- GnRH, respectively, whereas, G3 were treated with single dose injections with vitamin E & selenium, multi-vitamins, and phosphorus along with oral administration of Agrim® forte-feed supplement of vitamins & minerals for 20 days. The estrus response rates and presence of corpus luteum (CL) was higher 62% (13/21) in G2, whereas, the estrus response rates and presence of CL were lower 11.76% (2/17) and 29.41% (5/17) in G1. The non-returned to estrus and pregnancy rates were higher in G2, 61.90% (13/21) and 52.38% (11/21), respectively, whereas, lower in G1, 5.88% (1/17) and 5.88% (1/17), respectively. In G3, the estrus response rate was unable to observe, whereas, the presence of CL was 28% (5/18) following post 20 days per-rectum examination resulting 11% (2/18) pregnancy rates. In conclusion, progesterone-based hormone regimen (CIDR- PGF2α- GnRH) found to be effective. Nevertheless, this study provides some key information for further research.
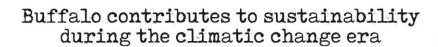
Keywords: Hormones, vitamin, minerals, fertility response.

POSTER PRESENTATION

SCIENTIFIC SESSION

ECOLOGY CLIMATE
WELFARE AND
SUSTAINABILITY

Buffalo contributes to sustainability during the climatic change era

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Abstract

Rapid urbanization, increased purchasing power and changing diets drive demand for richer diets and animal-based proteins, leaving more than 735 million undernourished people worldwide. Food security for a large population can be achieved through livestock production and promotion, to sustain food demand. However, there are concerns about ruminant livestock production, as ruminants produce methane contributing to climate change. Ruminant livestock, such as buffalo, provide nutrient-rich meat and milk together with hides, manure and animal power for agriculture and transportation in many countries. They can use feeds inedible for humans or live on land unsuitable for cultivation. They contribute to biodiversity and the livelihoods of many rural populations. The buffalo (*Bubalus bubalis*), with a total of 205 million heads could play a strategic role in the world economy and society due to its specific characteristics: rusticity, high capacity to convert fibre into energy, longevity, and adaptation to extreme areas such as wetlands where other ruminants cannot thrive. A multidisciplinary approach considering mitigation and adaptation strategies, breeding techniques, animal health and welfare, and social and economic contexts is requested to increase the sustainability of livestock and buffalo as well.

Keywords: Methane emissions, buffalo sustainable production, biodiversity, GHG mitigation strategies.

Livestock sustainability

According to The Global Agenda for Sustainable Livestock (GASL, 2022), the definition of Livestock sustainability refers to production approaches that simultaneously meet long-term conditions to ensure society's food and nutrition security, livelihoods and economic growth, animal health and animal welfare and stable climate and efficient resource use (the four livestock sustainability domains) to contribute to sustainable food systems. Two significant elements drive the implementation of sustainable livestock solutions. Firstly, the sector's diversity and, secondly, the demand for livestock commodities (Schneider and Tarawali, 2021).

Food and Agriculture Organization of the United Nations (FAO) estimates that livestock accounts for approximately 40% of global agricultural gross domestic product (GDP). It contributes to 34% of worldwide protein intake and 18% of dietary energy. It is estimated that 1.3 billion people, including over 600 million of the world's poorest and most vulnerable farmers and pastoralists, keep livestock and rely on it as an essential source of income (FAO, 2020).

The global population will exceed 9 billion by 2050, and this growth will inevitably lead to an increased demand for animal proteins (meat and milk) as people's standard of living improves. The global food demand is expected to increase by 35% to 56% between 2010 and 2050, while the population at risk of hunger is likely to change by −91% to +8% over the same period. If climate change is considered, the ranges increase slightly (van Dijk, et al., 2021). Nevertheless, ruminants are responsible for the production of methane, (5.8% of the total anthropogenic output - Gerber et al., 2013) and this has led to concerns about the sustainability of their production.

The livestock sector is confronted with several challenges including climate change, water scarcity, desertification, and land erosion. While the sector may have contributed to the exacerbation of these issues, it can also contribute to their resolution within an agroecological and environmental framework, while safeguarding biodiversity (Thompson et al., 2023). The livestock sector is also linked to the significance of different ecosystem types, management methods, and local needs and traditions, exhibiting

considerable diversity. These range from intensive to extensive, from cold to tropical, and from highly technological to local traditional. Consequently, the most suitable approaches depend on the context and cannot be integrated into a single global model (Leroy et al., 2022).

The implementation of effective measures to combat climate change through the utilization of livestock agrifood systems is of paramount importance. However, this endeavour must not compromise the attainment of other sustainability objectives, particularly those about the eradication of poverty and the achievement of zero hunger. Consequently, it is essential to strike a balance between the advantages of animal food sources and livestock rearing for nutritional, health and well-being outcomes, and the pressing necessity to curtail GHG emissions to address the climate crisis, which also jeopardizes food security.

The shaping of a sustainable future will depend upon an understanding of both the inherent diversity and complexity of livestock and agri-food systems. This understanding must be accompanied by an awareness of the particular motivations and challenges that stakeholders face during periods of transformative change. What is effective for a producer in a capital-intensive system may not necessarily be the same as what is effective for a pastoralist or a mixed crop-livestock smallholder (FAO, 2023).

To obtain a vast range of food and services, livestock utilize vegetable resources that would be inedible to humans and/or live on land unsuitable for cultivation. Ruminants, particularly when fed with feedstuffs produced on land unsuitable for primary cropping or by-products from agro-industrial processes, can be a net contributor to human edible food (Van Zanten et al., 2018).

Furthermore, they maintain and enhance protein and essential micronutrient supply (zinc, calcium, vitamin B12, and riboflavin), difficult to obtain from vegetable crops (Leroy et al., 2023) and provide a valuable source of income for small-scale farmers in developing countries.

Among ruminants, buffalo (*Bubalus bubalis*) could contribute to sustainability for its specie-specific characteristics: its high ability to convert row fibre into energy, its rusticity, its ability to adapt to different climatic environments (cold, tropical, or swampy), and its longevity, which is always higher than cattle, all along with other minor characteristics.

Concerns about livestock

The complexity of the food system is often overlooked in the general debate, with the three interconnected arguments that consumption of animal-source foods causes harm to human health, to the planet, and to animals themselves related to health hazards, climate change, and animal welfare (Leroy et al., 2023) being reduced to a simplistic narrative that fails to acknowledge the crucial role of livestock in supporting millions of people worldwide, with up to 12% of the global population depending on it for their livelihood, both in developing and developed countries.

There is an increasing concern that the demand for animal products, associated with population growth, increase in lifespan, and improved economic welfare, particularly in developing countries, will place an unsustainable burden on the environment (Salter, 2017). Furthermore, it is important to recognize that animal production yields diverse foods, including dairy and meat. Each of these foods is produced uniquely, displaying distinct biochemical and nutritional properties. Additionally, they are produced in regions with varying ecological contexts and consumed by populations with specific nutritional, economic, and cultural needs. Consequently, the intake of animal-source foods varies considerably between geographical regions and socioeconomic categories.

Climate change

Methane is a greenhouse gas (GHG) far less abundant than CO_2, yet it has a global warming potential that is 28 times more powerful on a 100-year scale (Jackson et al., 2020). The balance between sources and sinks is the primary factor that determines the concentration of methane in the atmosphere. The sources of methane are diverse, including biogenic sources such as wetlands, agriculture, waste/landfill, and permafrost; thermogenic sources, such as fossil fuels; pyrogenic sources, such as biomass and biofuel

burning; and mixed sources. The sink is mainly methane oxidation in soil (Saunois et al., 2016).

Agriculture contributes to total anthropogenic greenhouse gas (GHG) emissions, with a percentage varying from 8 to 18% (Hristov et al., 2013). Most global estimates include feed production, land use change, energy (not only as farm inputs and feed, but also other activities such as animal housing and ventilation), and product processing.

Livestock contributes to GHG emissions primarily through enteric fermentation, manure as methane and nitrous oxide, and different manure management systems, which generate varying levels of emissions. Among ruminants, cattle are responsible for 65% and buffaloes for 8% of direct emissions (Steinfeld et al., 2019).

Climate change can increase extreme weather conditions, which can adversely affect livestock productivity directly and indirectly. The increase in temperatures has resulted in reduced growth and reproductive efficiency, reduced milk and meat production, as well as animal health, making livestock vulnerable to new diseases. Furthermore, the availability of fodder and water is also affected by climate extremes and seasonal variations. Global food security is threatened by climate change and its adverse impact on the production of livestock.

Adaptation and mitigation strategies

Two possible approaches to achieving climate-smart outcomes in the rearing of livestock: 1) adaptation to climatic changes and 2) mitigation of greenhouse gases (Rojas-Downing et al., 2017). Integrating these two aspects can exploit synergies and minimize trade-offs between mitigation and adaptation.

Adaptation approaches may encompass a range of strategies, including the encouragement of resilient livestock farming practices, alterations to production and management systems, scientific and technological advancements, governance and policy alterations, and the modification of farmers' attitudes and adaptive capacity (IFAD, 2018). To ensure their efficacy, measures of adaptation must integrate principles of agroecology, such as improved circularity, while limiting competition for feed and food resources. Nevertheless, these measures must remain respectful of the diversity of ecosystem contexts, the availability of resources, and the various social and economic needs of local populations (Thompson et al., 2023). The use of feed sources with increased drought tolerance, which results in higher biomass and greater resilience to extreme environmental conditions, could prove to be a more sustainable approach. Additionally, the selective breeding of livestock to possess greater heat tolerance and reduced energy requirements might assist in ensuring their performances, thereby reducing the impact of any potential production fluctuations (Brito et al., 2021). A total of over 38 species of farmed animals but more than 8,800 local breeds are adapted to specific contexts (FAO, 2024). Due to their greater ability to cope with stressful environments, indigenous breeds display higher resilience levels than exotic breeds.

A massive worldwide research effort has been devoted to finding successful mitigation strategies that can be summarized into three categories: changes in animal and feed management (i.e., genomic selection, rational grazing, agroforestry, animal health manure management), diet formulation (i.e., forage quality, lipids, seaweeds, additives), and rumen manipulation (i.e., vaccination, defaunation, direct-fed microbial) (Hristov et al., 2013; Veneman et al., 2016; Arndt et al., 2022; Tseten et al., 2022; Chiariotti, 2023). All of them potentially involve changes in the rumen microbiome (Tapio et al., 2017), thus, lowering methane emissions would benefit the environment and eventually the livestock production efficiency.

Microbial fermentation in the rumen is a crucial aspect of the digestive process in ruminants, as it enables the animals to utilize lignocellulosic material, producing both volatile fatty acids (VFAs) and microbial protein. This protein is an important source of both energy and protein for the ruminant host, while the rumen provides an ideal environment for microbial growth and development (Cammack et al., 2018). However, microbial fermentation has the potential to cause environmental harm through the emission of methane and the excretion of excessive quantities of nitrogen in feces and urine. Furthermore, rumen methane production results in the loss of energy from 2% to 12% of the total energy intake for animal growth and production (Johnson and Johnson, 1995).

Nevertheless, according to Arndt et al. (2022), methane yield is not the only relevant measure, other methane emissions and animal performance metrics should be considered to estimate the feasibility of mitigation strategies.

Sustainable management

The role of livestock in agriculture is multifaceted and indispensable. They are a vital component of ecological systems, capable of transforming non-edible biomass from pasture systems into human food, recycling plant nutrients back into the soil, enhancing soil health, and sequestering carbon (Thompson et al., 2023). Integrating crop and livestock farming is an effective strategy to reduce emissions associated with animal production (Borghese et al., 2023). The integration of trees and meadows in agroforestry systems (e.g., silvopastoral) has the potential to offer financial benefits to farmers while simultaneously enhancing crop yields and reducing the environmental burden. Furthermore, research has demonstrated that pasture-based production systems are more conducive to animal welfare and biodiversity, as they facilitate more natural animal behaviour. Grazing management and soil management practices include the implementation of rotational grazing, cover cropping, and conservation tillage. Rotational grazing entails modifying grazing patterns to prevent overgrazing and allow for regrowth of vegetation. Cover cropping, on the other hand, involves planting specific crops after harvesting to enhance soil fertility while conserving soil moisture and reducing erosion. The practice of conservation tillage is defined by minimal mechanical disturbance of the soil, which helps to retain a significant portion of the crop residues on the soil surface, thus providing organic matter for soil nutrition. Additionally, practices such as rotational grazing and fodder banking have the potential to enhance the efficiency of production on smallholder farms, whilst also serving to prevent further degradation of the land. These methods reduce methane emissions from the soil along with reducing erosion and water pollution (Cheng et al. 2022). Nevertheless, the adoption of optimal sustainable farming systems is not a straightforward process, as they may yield disparate outcomes. In some instances, these systems may prioritize biodiversity conservation and carbon sequestration, whereas, in others, they may favour increased production (Sabia et al., 2018). For instance, systems based on grazing may demonstrate superior environmental performance due to the reduced inputs required for production, although this may necessitate the use of more land.

A potential solution to this issue is the replacement of traditional animal feeds with more carbon-friendly alternatives (Grossi et al., 2019). For example, soybean meal and maize are both highly carbon-intensive due to the large amounts of inputs required for their production. Alternatives such as barley, alfalfa, and sorghum are more sustainable. Additionally, some livestock farms are now utilizing by-products from agro-industrial residues, which could help reduce waste and disposal costs. It can be reasonably argued that the dissemination of knowledge regarding the management of livestock and the sharing of information among farmers represents a significant intervention in the pursuit of sustainable livestock production. The capacity of farmers to manage their resources is enhanced when they have access to accurate and timely information, which in turn can lead to improved yields and a reduction in emissions (Monteiro et al., 2021).

Recent innovations in sustainable livestock production are being investigated by researchers and those responsible for governance to respond to the challenges posed by climate change in a way that maintains the environment and an efficient food system. In various fields, innovations can facilitate the creation of new solution spaces, including smart farming, genetics, robotics, environmental monitoring, and the development of novel business models. Advancements in informatics have enabled the advancement of cameras, sensors, and environmental technologies in buffalo farming included (Meo Zilio et al., 2020; Neglia et al., 2023). Networking and farm management software allow farmers to enhance animal management based on individual needs, enabling informed decision-making. Through these techniques, for instance, farmers can monitor soil fertility and reduce the input of fertilizers to maintain soil health.

The utilization of renewable energy sources in sustainable livestock production has the potential to reduce both carbon emissions and reliance on fossil fuel sources, while simultaneously facilitating the generation of green energy for the farm (Twine, 2021). The integration of solar power, wind turbines, and biogas

digesters in this context has been observed to result in cost savings, which in turn can be reinvested into reducing the emissions associated with farming (Hou et al., 2020).

Buffalo as a tool for sustainability

The buffalo (Bubalus bubalis), plays a strategic role in the world economy and society, with a total of 205 million heads (a 4.2 % increase in the last ten years), although 98% of the total world buffalo population is present in Asia, particularly in India, Pakistan, and China.

This animal is a major source of food (milk and meat), power, fuel, and by-products (hides, hoof, and bones), as well as manure to be used as fertilizer, or energy source, especially in developing countries.

One of the characteristics that make the buffalo so widely used is its ability to convert fibre into energy. Numerous studies indicate the superiority of buffalo over cattle in food conversion and the use of fodder and agricultural by-products with low nutrient content (Terramoccia et al., 2013), thanks to a better rumen fermentation (Wanapat et al., 2000) and nitrogen utilization (Neglia et al., 2013; Naveed-ul-Haque et al., 2018). In addition, from a recent molecular study, buffalo rumen in comparison with bovine rumen was confirmed to have a greater potential for fibre degradation and appears to have less potential for gastroenteric methane production (Tong et al., 2022). Nevertheless, an improper feeding regimen and food availability inevitably impact reproductive and productive performances, by increasing mortality rates, delay in resumption of cyclicity, longer calving interval, and reduced growth rates (Sarwar et al., 2009; Pasha, 2013; Sethi et al., 2021).

Other important characteristics of the buffalo are its rusticity, its ability to adapt to different climatic environments (from hot-humid to very cold), and its longevity, which is always higher than that of the bovine.

To maintain their body temperature in the presence of elevated temperatures, buffalo engage in a range of thermoregulatory behaviours, including seeking shade, moderating sweating, panting, and wallowing in mud. The optimal climatic conditions for the growth and reproduction of water buffalo are a temperature range of 13 to 18°C, a relative humidity of 55 to 65%, and a medium level of sunshine, however, it has a high ability to adapt to different climatic environments (from hot-humid to very cold) (El Debaky et al., 2019).

The water buffalo's coat is characterized by a dense hair coat present at birth and during early growth. Their epidermis is characterized by a thick layer of melanin that gives their skin a distinctive black colour and shields it from harmful UV rays (Marai & Habeeb, 2010). In addition, sebum, a fatty substance that acts as a lubricant, is secreted by well-developed sebaceous glands. During periods of high heat, the sebaceous layer melts and shines, reflecting a greater proportion of solar radiation and reducing the external thermal burden on the animal (El Debaky et al., 2019).

Buffalo, an animal adapted to survive in adverse conditions, plays a crucial role in maintaining the cleanliness of riverbeds and wetlands in areas where rice cultivation is prevalent, particularly in terraced areas where mechanization is not a viable option and cattle cannot survive. The buffalo is well-suited for wetlands due to the broad articulation of its hoof, which allows it to navigate muddy terrain with greater ease than other species during the rainy season. This attribute has made the buffalo a highly regarded choice for draught power in numerous countries. It should be emphasized that this goes hand in hand with buffalo products of high quality.

Buffalo meat has a lower calorie content, lower cholesterol, an unsaturated fatty acid/saturated fatty acid ratio >1, a higher protein level, and a higher iron content (>1.5mg/100g) compared to beef (Contò et al., 2022). It possesses many appealing characteristics including red colour, low connective tissue, desirable texture, water-holding capacity, myofibrillar fragmentation index, and emulsifying capacity (Kandeepan et al., 2013).

Buffalo milk also plays an important role in human nutrition, especially in developing countries. It is richer than cow's milk in all major constituents, such as fat (6.6-8.8%), lactose (4.5-5.2%), protein (3.8-4.5%), casein, and ash (Abd El-Salam and El-Shibiny, 2011). These chemical characteristics also

allow for a cheese yield twice as high as that normally obtained with cow's milk. Furthermore, the presence of the A2 versus A1 variant of β-casein makes this milk more like human breast milk and therefore probably easier to digest (de Oliveira et al., 2021).

Conclusion

The Buffalo population has increased by 4.2% over the past decade, reaching a total of 205 million heads. This increase has the potential to influence the global economy and society due to the species' distinctive characteristics, including its rusticity, capacity to convert fibre into energy, longevity, and ability to thrive in extreme environments such as wetlands, where other ruminants cannot thrive.

A multidisciplinary approach embracing the wider and varied aspects of nutrition, landscapes, and culture considering the environment, livestock management, animal health and welfare, and social factors is requested to deal with the environmental issues of livestock and there is a considerable margin for correction and improvement of livestock production. So, when livestock production is done well respecting local ecosystems and social contexts it could improve public health and environmental resilience.

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KEYNOTE–ECOLOGY CLIMATE WELFARE AND SUSTAINABILITY

Waste management practices of buffalo farms in selected areas of Bangladesh

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Abstract

Proper management of farm waste may contribute to profitable buffalo farming by lowering production costs. Otherwise, it may generate environmental and health challenges. Thus, the current study aimed to investigate the existing buffalo farm waste management practices and the condition of farm waste drainage water in Bangladesh. A purposive survey was conducted through a structured questionnaire. Survey data was collected from 200 buffalo-rearing farms from five upazilas (Companiganj, Bauphal, Ishwardi, Godagari, and Chorfession). Farm waste drainage water samples were collected from the same areas for laboratory analysis. Results showed that the average herd size of buffaloes was 16.1±8.2, 31.7±23.7, 15.5±7.1, 11.3±5.6 and 17.8±17.3 in the Godagari, Companiganj, Bauphal, Ishwardi, and Chorfession upazilla, respectively. Among these five upazila, farmer practices the rearing systems of buffaloes were intensive (2%), semi-intensive (32%), and extensive (66%) farming system. About 98.5±2.23% of farmers had no farm drainage systems. Farmer processes their buffalo dung through solid storage (22.8%), burned for fuel (29.9), pasture (35.78%), liquid/slurry (8.5%), and lagoon (3.02%). About 54% of farmers daily spread their fresh solid storage dung on the cropland. Farmers cleaned their buffalo sheds once a day (52.5%), twice a day (46.5%), and three times a day (1.0%). Farmer's responses on problems regarding waste management were lack of manpower (31.2%), lack of adequate space (16.5%), lack of relevant equipment/machinery (8.5%), and lack of willingness (43.8%). The ammonium nitrogen (NH_4N) and EC (ds/m) levels of drainage wastewater were higher in Ishwardi (29.6±2.32; 2.82±2.79) and lower in Bauphal (0.42±0.04; 0.31±0.16). The water pH was higher at Godaghari (7.28±0.28) and lower at Bauphal (6.3±0.99). It may be concluded that the knowledge developed during this study will help future planning for the country's buffalo farm waste management practices.

Keywords: Buffalo waste, management practices, and drainage water quality.

Transforming buffalo farming in the climate change landscape of Bangladesh

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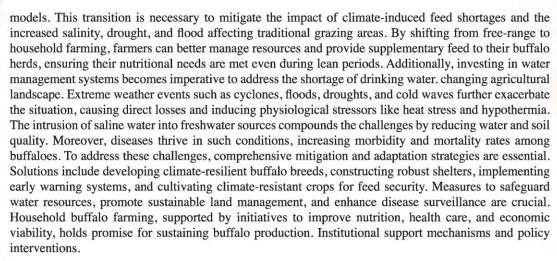
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Abstract

Climate change poses significant challenges to buffalo production in Bangladesh, impacting various aspects of husbandry and threatening the sustainability of the sector. Diminishing grazing land due to salinity, illegal land acquisition, and cereal crop expansion restricts buffaloes' access to essential nutrition, leading to reduced milk and meat production. Now the time for shifting from free-range to household farming, intensive or semi-intensive model in the face of climate change challenges, buffalo farmers are forced to adapt their practices to ensure sustainability and productivity. The scarcity of grazing land presents a significant obstacle, pushing farmers towards adopting intensive or semi-intensive farming

ORAL PRESENTATION

models. This transition is necessary to mitigate the impact of climate-induced feed shortages and the increased salinity, drought, and flood affecting traditional grazing areas. By shifting from free-range to household farming, farmers can better manage resources and provide supplementary feed to their buffalo herds, ensuring their nutritional needs are met even during lean periods. Additionally, investing in water management systems becomes imperative to address the shortage of drinking water. changing agricultural landscape. Extreme weather events such as cyclones, floods, droughts, and cold waves further exacerbate the situation, causing direct losses and inducing physiological stressors like heat stress and hypothermia. The intrusion of saline water into freshwater sources compounds the challenges by reducing water and soil quality. Moreover, diseases thrive in such conditions, increasing morbidity and mortality rates among buffaloes. To address these challenges, comprehensive mitigation and adaptation strategies are essential. Solutions include developing climate-resilient buffalo breeds, constructing robust shelters, implementing early warning systems, and cultivating climate-resistant crops for feed security. Measures to safeguard water resources, promote sustainable land management, and enhance disease surveillance are crucial. Household buffalo farming, supported by initiatives to improve nutrition, health care, and economic viability, holds promise for sustaining buffalo production. Institutional support mechanisms and policy interventions.

Keywords: Transformation, Buffalo farming and Climate change.

Redesigning buffalo farming practices in Bangladesh toward a sustainable milk production system

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Abstract

Buffaloes are known for producing milk with minimal investment and labor compared to cattle. Their milk contains higher percentages of fat, protein, lactose, and minerals (calcium and potassium) than cow milk. Despite its importance, the buffalo milk industry in Bangladesh faces challenges like low productivity, outdated farming practices, and limited access to modern technologies and resources. A sustainable buffalo milk production system was designed using Reflexive Interactive Design (RIO in Dutch) to address these issues. This design focuses on key functions including nutrition, disease assessment, udder health, and milk quality. However, this design remains theoretical and has not been tested in real-world settings. Implementing it practically offers a great opportunity to observe its success. The proposed study aims to address these challenges through a participatory action research framework, involving key stakeholders in the design, testing, and refining of innovative solutions over a three-year study. The proposed design suggested arranging a workshop involving farmers, processors, government officials, NGOs, stakeholders, and IT experts to gather insights and formulate strategies. Following this, a pilot study will be conducted on selected buffalo farms of various rearing systems to test the proposed interventions. The concept will be introduced in real-world settings, followed by systematic observation of the outcomes. The results will be evaluated and presented to stakeholders for feedback. Based on the feedback, the design will be refined and re-implemented in the pilot locations. The outcomes of the refined

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design will be observed again to ensure improvements. This cyclical approach ensures a dynamic and inclusive process, allowing continuous refinement and adaptation of the milk production system to enhance efficiency, productivity, and sustainability in Bangladesh. Ultimately, the study anticipates economic benefits for buffalo farmers, including increased income and stability, alongside evidence-based policy recommendations to support the sector's growth and sustainability.

Keywords: Milk, system design, sustainability, stakeholder participation, Reflexive interactive design.

Investigation of sprinkler cooling system on reducing heat stress in swamp buffalo

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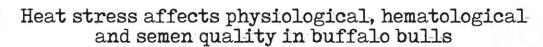
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Abstract

Heat stress negatively impacts dairy buffalo health and productivity, a concern that has received limited research attention in Thailand. This study aimed to evaluate the effectiveness of a sprinkler cooling system in reducing and managing body temperature in swamp buffaloes. Six swamp buffalo cows were selected and divided into 2 groups; a control group which received no treatment, and a treatment group, which was provided with a sprinkler from 8 a.m. to 3 p.m. for 2 weeks. All buffaloes were monitored for intravaginal body temperature and respiratory rate. Also, ambient temperatures were recorded once a week randomly (for 24 hrs). The results found that the buffaloes in the treatment group showed a lower and more stable body temperature and respiratory rate than the control group during treatment with the sprinkler cooling system. This study demonstrates that the use of a sprinkler cooling system can effectively reduce heat stress in swamp buffaloes, offering a practical solution to improve animal welfare and productivity in hot climates.

Keywords: Cooling system, sprinkle, heat stress.

ORAL PRESENTATION

Heat stress affects physiological, hematological and semen quality in buffalo bulls

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Abstract:

Buffaloes, with their dark skin and underdeveloped sweat glands, are particularly make them susceptible to heat stress, which is a common challenge in the tropical climate of Bangladesh. Despite frequent exposure to heat, little was known about heat stress in buffaloes across the country. Therefore, the study was aimed to quantify the responses of buffalo in heat stress conditions. This research was carried out with 37 buffalo bulls (3-5 years age) housed in an open shed in BLRI Buffalo Research Farm, Savar, Dhaka. In the current research, heat stress indicatory physiological parameters (heart rate-HR, skin temperature-ST, scrotal temperature-SCT, and respiration rate-RT), hematological responses (Hemoglobin-Hb, Red Blood Cell-RBC, and Packed Cell Volume-PCV) as well as semen quality assessing parameters (static sperm, mass motility, progressive motility, and normal sperm ratio) were recorded. These measurements were taken at various period of the day based on the temperature humidity index (THI), which had values ranging from 74 to 90. The THI was categorized into 3 THI groups- i) comfort zone (THI-74 to78), ii) moderate heat stress (THI-79 to 86), and iii) severe heat stress (THI 87 and above). The findings revealed that heat stress increased (P<0.001) thermoregulatory responses such as HR, ST, SCT, and RR at THI-86 and THI-90. The core body temperature of the animal was determined by its RT. Notably, RT was elevated by 0.420C and 0.580C from the comfort zone. Additionally, the aggravated thermal stress led to reduction (P<0.01) in the hematological parameters (Hb, RBC, and PCV). However, a positive correlation (P<0.01) was found between increased THI and HR (0.37), RT (0.11), ST (0.38), SCT (0.21), and RR (0.38) but negatively correlated with Hb (-0.61), RBC (-0.53) and PCV (-0.51), respectively. Furthermore, Buffalo bull's semen quality drastically deteriorated (P<0.001) due to the consequences of heat stress. This study concludes by highlighting that heat stress adversely affects the physiological, hematological, and reproductive performance of buffalo bulls.

Keywords: Climate crisis, heat stress, responses, core body temperature, semen.

Influence of international workshop on stakeholders' perception of buffalo farming in Bangladesh

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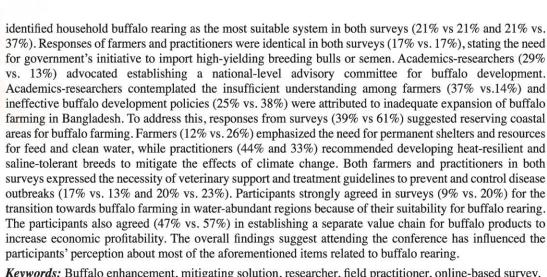
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Abstract

An online-based pre-and post-workshop survey was conducted among participants of the International Buffalo Workshop 2024, held from 2-5 March 2024 in Dhaka, Bangladesh. The survey aimed to evaluate changes in participants' perceptions about buffalo farming, product chains, and diseases by attending the conference. The distribution of participants in pre-and post-survey included academics-researchers (42 vs. 24), veterinary practitioners (29 vs. 24), and farmers (26 vs. 20). Both academics-researchers and farmers

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identified household buffalo rearing as the most suitable system in both surveys (21% vs 21% and 21% vs. 37%). Responses of farmers and practitioners were identical in both surveys (17% vs. 17%), stating the need for government's initiative to import high-yielding breeding bulls or semen. Academics-researchers (29% vs. 13%) advocated establishing a national-level advisory committee for buffalo development. Academics-researchers contemplated the insufficient understanding among farmers (37% vs.14%) and ineffective buffalo development policies (25% vs. 38%) were attributed to inadequate expansion of buffalo farming in Bangladesh. To address this, responses from surveys (39% vs 61%) suggested reserving coastal areas for buffalo farming. Farmers (12% vs. 26%) emphasized the need for permanent shelters and resources for feed and clean water, while practitioners (44% and 33%) recommended developing heat-resilient and saline-tolerant breeds to mitigate the effects of climate change. Both farmers and practitioners in both surveys expressed the necessity of veterinary support and treatment guidelines to prevent and control disease outbreaks (17% vs. 13% and 20% vs. 23%). Participants strongly agreed in surveys (9% vs. 20%) for the transition towards buffalo farming in water-abundant regions because of their suitability for buffalo rearing. The participants also agreed (47% vs. 57%) in establishing a separate value chain for buffalo products to increase economic profitability. The overall findings suggest attending the conference has influenced the participants' perception about most of the aforementioned items related to buffalo rearing.

Keywords: Buffalo enhancement, mitigating solution, researcher, field practitioner, online-based survey.

CX43 and oxidative stress are the targets of BCB staining to predict the developmental potential of buffalo oocytes

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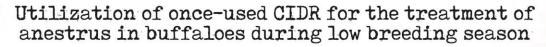*Corresponding author: biotech@gxbri.com

Abstract

Brilliant cresyl blue (BCB) staining is used to differentiate and predict oocyte developmental competence. However, it has not been reported whether BCB staining can be used to stain and identify buffalo COCs to determine the expression level of gap junction proteins between granulosa cells and oocytes, and the role of oxidative stress in the process. In this research, we tried to explain the predictive mechanism of BCB staining on the developmental potential of buffalo oocytes from the transmission of antioxidant capacity. The oocytes were divided into BCB+ and BCB- groups using BCB staining technique. Then used in vitro maturation, in vitro fertilization and embryo culture techniques of buffalo oocytes to analyze their developmental potential, and used immunofluorescence staining to detect the expression level of CX43 protein, DCFH-DA probe staining to detect ROS levels, and qPCR to detect the expression levels of the antioxidant related genes SOD2 and GPX1. Our results showed that, the in vitro maturation rate, embryo cleavage rate, and blastocyst rate of buffalo oocytes in the BCB+ group were significantly higher than those in the BCB- group and the control group ($P<0.05$). The expression level of CX43 protein in the BCB+ group were higher than that in the BCB- group both before and after maturation ($P<0.05$). The intensity of ROS in the BCB+ group were significantly lower than that in the BCB- group ($P<0.05$), and the expression levels of the antioxidant-related genes SOD2 and GPX1 in BCB+ group were significantly higher than those in the BCB- group ($P<0.05$). BCB staining could effectively predict the developmental potential of buffalo oocytes. The results of BCB staining were positively correlated with the expression of gap junction protein and antioxidant-related genes and negatively correlated with the ROS level, suggested that the mechanism of BCB staining in predicting the developmental potential of buffalo oocytes might be closely related to antioxidant activity.

Keywords: BCB staining, buffalo oocyte, developmental potential prediction, gap junction, oxidative stress.

Utilization of once-used CIDR for the treatment of anestrus in buffaloes during low breeding season

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Abstract

Controlled internal drug release (CIDR)-based protocols are effective to treat summer anestrus in buffaloes. However, the cost of CIDR and other hormones (specially GnRH) makes the protocol expensive. Therefore, the present study evaluated the effectiveness of: (i) once-used versus new CIDR in CIDR Co-synch protocol, and (ii) once-used CIDR Co-synch protocol 'with' versus 'without initial GnRH' for the treatment of summer anestrus in Murrah-crossbred buffaloes during low breeding season. In experiment 1, in anestrous buffaloes, the effectiveness of once-used CIDR (n=31) versus new CIDR (n=19) in the CIDR Co-synch protocol was compared. Experiment 2 utilized the once-used CIDR in the CIDR Co-synch protocol, and compared the efficacy between 'with' (n=18) versus 'without' (n=11) initial GnRH administration. Within the CIDR Co-synch protocol, the once-used CIDR showed similar effectiveness to new CIDR in terms of estrus expression, ovulation and pregnancy outcomes. Also, the local inflammatory response into the vagina of treated buffaloes was similar between new and once-used CIDR groups. Pregnancy outcome from FTAI was affected by the size of the CL during 8-9 d after FTAI. Although the FTAI-pregnancy rate was 16% (8/50), the overall pregnancy from FTAI and natural breeding within two months after FTAI was 42% (21/50). In experiment 2, there was no significant difference between two treatment groups in estrus expression, ovulation and pregnancy rates, with overall rates of 93%, 69%, and 34.5%, respectively. The overall pregnancy outcome up to 2 months post-FTAI was 48.3%. In conclusion, the once-used CIDR was as effective as the new CIDR for resuming reproductive function in anestrous buffaloes during low breeding season. Furthermore, for the treatment of anestrus in buffaloes, the 'once-used CIDR Co-synch protocol without initial GnRH' proved equally effective as the protocol with initial GnRH, suggesting potential cost savings by omitting the initial GnRH dose without compromising the efficacy.

Keywords: Buffalo, low breeding season, summer anestrus, once-used CIDR, CIDR Co-synch protocol, GnRH.

Salivary fern crystallization pattern-based timing of insemination and its association with conception in the buffalo

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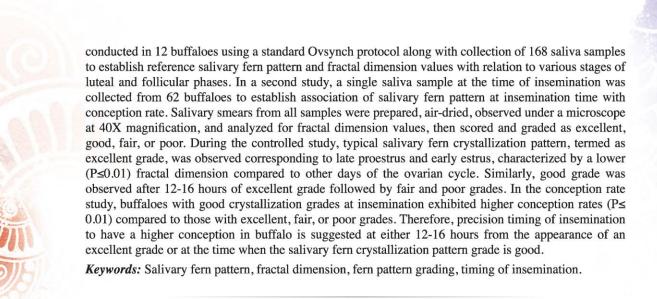
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Abstract

The use of salivary fern patterns in buffaloes offers a simple, non-invasive, and inexpensive alternative to other estrus detection methods, addressing the challenges of silent heats, inaccurate estrus detection, and improper timing of artificial insemination. This study investigated the time to insemination based on salivary fern crystallization pattern and its association with conception in buffalo. A controlled study was

POSTER PRESENTATION

conducted in 12 buffaloes using a standard Ovsynch protocol along with collection of 168 saliva samples to establish reference salivary fern pattern and fractal dimension values with relation to various stages of luteal and follicular phases. In a second study, a single saliva sample at the time of insemination was collected from 62 buffaloes to establish association of salivary fern pattern at insemination time with conception rate. Salivary smears from all samples were prepared, air-dried, observed under a microscope at 40X magnification, and analyzed for fractal dimension values, then scored and graded as excellent, good, fair, or poor. During the controlled study, typical salivary fern crystallization pattern, termed as excellent grade, was observed corresponding to late proestrus and early estrus, characterized by a lower (P≤0.01) fractal dimension compared to other days of the ovarian cycle. Similarly, good grade was observed after 12-16 hours of excellent grade followed by fair and poor grades. In the conception rate study, buffaloes with good crystallization grades at insemination exhibited higher conception rates (P≤ 0.01) compared to those with excellent, fair, or poor grades. Therefore, precision timing of insemination to have a higher conception in buffalo is suggested at either 12-16 hours from the appearance of an excellent grade or at the time when the salivary fern crystallization pattern grade is good.

Keywords: Salivary fern pattern, fractal dimension, fern pattern grading, timing of insemination.

Biometric analysis and growth patterns of Thai swamp buffalo: insights from the 2024 conservation and development initiative

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Abstract

The Thai Swamp Buffalo Conservation and Development Day 2024, held on January 13-14 at the Dairy Research and Development Center in Nakhon Ratchasima Province (Thailand), aimed to enhance the quality and characteristics of the Thai swamp buffalo (TSB; Bubalus bubalis carabanesis) breed, increase their population, and improve farmer incomes by promoting local wisdom and traditional agricultural practices. This study evaluated the body weight (BW) and size of TSB across different age groups (10-18, 18-24, 24-36, and 36-48 months) and color variations (black and pink) for both sexes. Data were collected from 150 buffaloes raised by 101 farmers across 33 provinces in Thailand, focusing on measurements of BW, shoulder height (SH), heart girth (HG), and body length (BL). Results indicated significant BW, SH, HG, and BL growth with age in all categories. Black female TSB showed BW ranging from 495.13 ± 128.08 kg at 10-18 months to 753.00 ± 144.22 kg at 24-36 months, while black males reached 1,097.90 ± 179.59 kg at 36-48 months. Pink female TSB exhibited BW growth from 493.33 ± 59.97 kg at 10-18 months to 719.00 ± 4.24 kg at 36-48 months, and pink males increased from 507.67 ± 86.21 kg at 10-18 months to 837.50 ± 84.36 kg at 36-48 months. Statistical analysis revealed that BW was most strongly associated with HG (P < 0.01), followed by BL and SH, suggesting that HG can be a reliable indicator for selective breeding programs. These findings provide critical insights into the growth patterns of TSB, supporting targeted breeding strategies to enhance growth and carcass quality while preserving genetic purity. The implications of this research extend to improved economic outcomes for farmers and the conservation of traditional agricultural practices, filling a vital gap in the biometric profiling of this valuable breed.

Keywords: Thai swamp Buffalo, body weight, heart girth, selective breeding, biometric profiling.

SCIENTIFIC SESSION

FEEDING
AND
NUTRITION

Adaption of improved feeding technologies in buffalo farming

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Abstract

Traditional practices are predominant in buffalo farming in Bangladesh. Therefore, their productivity is low. Proper nutrition improves the productivity of buffalo. The adaptation of nutritional technology in buffalo farming is associated with farmers' interest and willingness. This research aimed to analyze the farmers' perception of improved feeding technologies in buffalo rearing and their willingness to pay (WTP) for the adoption of the technology. A total of 250 farmers were randomly selected from five upazilas (Ishurdi, Ramgoti, Gangachara, Anowara, and Fenchugonj) using Cochran's sample size formula. Contingent valuation method (CVM) and the close-ended double-bound dichotomous choice question were used to assess the WTP. The average herd size of buffalo was 11.52±0.98 heads. The rearing system was 6.4% intensive, 43.0% semi-intensive, and 50.6% extensive in the studied areas. About 11.2% of farmers used improved feed supplements for their buffalo. Willingness of farmers to pay for total mixed ration (TMR), urea molasses straw (UMS) and urea treated straw (UTS) were 50.4, 45.2 and 34.8%, respectively. The average WTP premium price per kg TMR, UMS, and UTS ranged from 39 to 47, 20 to 27 and 12 to 21 BDT, respectively. The annual household income positively and significantly influenced farmers' WTP. Farmers were showed more positive perception on TMR (3.51±0.08) than UMS (3.09±0.08) and UTS (3.19±0.06). It may be concluded that there was a demand for improved feeding technology for sustainable buffalo farming.

Keywords: Buffalo rearing, adaption, feeding technologies, Socio-economic factors.

Protein-rich pellet starter enhance body weight gain in suckling buffalo calves

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Abstract

The weaning stage is a critical period in the development of buffalo calves, significantly impacting their future growth and productivity. Thus, the research was undertaken to evaluate the effects of protein-rich pellet starter on the growth performance of buffalo calves during the weaning stage. A total of 10 buffalo calves aged between 7 to 8 days were selected and randomly assigned into two groups; T0 (32.48±3.45 kg body weight) and T1 (31.67±5.19 kg body weight), respectively. The T0 group received a concentrate mixture containing 15.31% CP in mesh form whereas T1 group received a protein-rich pellet starter containing 21.88% CP at a rate of 1% of body weight. All calves were suckled once in the morning. Adlibitum green roughage and clean drinking water were supplied regularly. The experiment was conducted for 180 days. Means were compared using a paired sample t-test. Regular body weight and feed intake data were recorded throughout the experimental period. Results indicated that calves body weight did not differ (P>0.05) at birth (29.94±1.71 vs. 28.38±1.86 kg), 30 days (40.86±1.97 vs. 42.51±4.13 kg)

ORAL PRESENTATION

and 90 days (57.23±4.83 vs. 69.67±3.39 kg) of age between T0 and T1 groups. However, body weight gains were higher (P<0.01) in T1 group at 120-day (61.82±4.60 vs 82.68± 4.46 kg), 150-day (67.70±6.27 vs 99.23±3.16 kg) and 180-day (80.3±6.69 vs 115.88±4.59 kg), respectively compared to T0 group. Body weight gains were 25.22, 46.61 and 44.30% higher in T1 group than T0 group at the age of 120-day, 150-day and 180-day, respectively. The feed intake and feed conversion ratio (FCR) were markedly better in the protein-rich pellet starter group. It may be concluded that protein-rich pellet starter can be an effective strategy for improving body weight gain in suckle buffalo calves.

Keywords: Pellet starter, body weight gain, buffalo calves.

A first methods for identification and characterization of lignin-degrading fungi discovered from water buffalo rumens

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Abstract

Lignin is one of the major obstacles to the degradation of plant cell walls, affecting the use of energy hidden in the particular biomass. In fact, It is an important aromatic heteropolymer that is forming a physical barrier and a big challenge in biomass utilization. The biological role of lignin is to increase cell wall integrity and protect it from the attack by pathogen. A fungus capable of hydrolyzing lignin was isolated from the rumen of buffalo, identified and charecterized as Aspergillus fumigates LF strain. Solid screening medium were used for screening lignin-degrading microbes.The rate of degradation sodium lignosulfonate was 9.7% after 7 days. Straw lignin and cellulose have showed favorable degradation rate while using Aspergillus fumigatus LF to treat corn stalk and rice straw, under anaerobic fermentation for the period of 30 days. It can be seen the degradation rate of ADF in corn straw and straw by strain LF in anaerobic incubator were 21.38% and 11.17% respectively. The enzyme activity test showed that the Aspergillus fumigatus LF strain can secrete acetyl esterase (AE) with an optimal pH of 8, and optimum temperature of 450C. The diversity of lignin degrading fungi in buffalo rumen is revealed. The results suggest that the lignin degrading fungi are abundant in the water buffalo rumen. The discovery of novel fungi with lignin degradability and the study of lignin degrading enzymes are important in the conversion of lignocellulose to biofuels and renewable chemicals. The study of Aspergillus fumigatus LF expands the range of fungi of lignin degradation and provides a novel fungi for application of lignocellulosic biomass.

Keywords: Buffalo rumen, lignin, *Aspergillus fumigatus* LF, acetyl esterase, isolation.

ORAL PRESENTATION

Evaluating residual feed intake for predicting growth efficiency in buffalo bulls

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Abstract

The feed efficiency determines the profitable livestock production systems. Residual Feed Intake (RFI), a prominent measure of feed efficiency is offering a reliable indicator independent of growth rate and body size. Therefore, the current research was under taken to identify the more efficient buffaloes through using RFI selection tool. Nineteen crossbreed buffalo bulls (average age- 15.59±5.75 months and body weight 227.52±43.48kg) were selected from Buffalo Research farm of BLRI. The experimental animals were fed roughage and concentrates feed based on their body weight for a period of 120 days. Daily feed intake (DMI), monthly body weight and blood samples were collected from the experimental animals. A metabolism trial was conducted for 7 days to determine RFI, DMI and nutrients digestibility. The bulls were selected as efficient or less efficient through regressing actual DMI on predicted DMI (kg/head/d) using a multiple regression model. Buffaloes with positive RFI values were low efficient (High RFI group) and buffaloes with negative RFI values were efficient (Low RFI group). Result indicated a significant (P<0.05) variation in RFI among the buffalo bulls (8 bulls in low RFI and 11 bulls in high RFI groups). Buffalo bulls with low RFI intake lower DMI (5.24±0.05 kg vs 5.44±0.04kg) compared to high RFI (P<0.05) maintaining similar average daily body weight gains (0.35±0.492kg vs. 0.33±0.38kg). Bulls in the low RFI group maintained body weight equal to that of the high RFI group despite consuming 0.42 kg less DM. The digestibility coefficients of nutrients were also higher in low RFI group. The blood metabolites profiles of glucose, triglycerides, cholesterol, HDL, LDL, ALT, AST, GGT, TP and phosphorus did not differ with RFI. It may be concluded that RFI is a valuable metric for predicting growth efficiency in buffalo bulls.

Keywords: Feed efficiency, RFI, buffalo bull selection.

ORAL PRESENTATION

SCIENTIFIC SESSION

GENOMICS
AND
BIOTECHNOLOGY

Omics for understanding reproductive performance of buffalo bulls under heat-stress

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Summary

Buffalo being an integral part of livestock keeping in Asia, is gaining global importance as a meat and dairy animal. With a population of 109.85 million, India possesses largest buffalo numbers, with significant contribution to livestock output and livelihood of the farmers. Reared under the tropical conditions, buffaloes suffer environmental stresses, reflected in the production and reproduction performance of the animals. In males, the summer stress with THI reaching upto 90, has catastrophic effect on semen quality with multiple parameters issues, affecting the supply of quality semen as part of AI program, to augment the animals' productivity. Different omics tools available now a days are helping us to have deep insights into the genes/pathways as well as mechanisms by which the heat stress plays role in compromising the reproductive performance of the animals. Here we discuss the epigenomics, tarnscriptomics and whole genome sequencing work being initiated to understand the heat stress impact on Murrah buffalo bulls' reproduction. Considering the volume of work reported in buffalo, there is a need to put extensive efforts to exploit the potential biomarkers, identified using these techniques, to ensure selection of animals, capable of producing quality semen throughout the seasons.

Keywords: Murrah bulls, heat stress, semen quality, epigenomics, transcriptomics, genome sequencing.

The integrated system of environment and living beings exist in harmony and exchange functional consequences in unbidden manner. In recent decades, the global warming and the ensuing climate change has posed a huge challenge to the animals, particularly the production animals, which are raised in plurality unlike the companion animals. Among livestock species, 98% of the global buffalo population is distributed in Asia, whereas merely 46% of cattle population is present in Asia, indicating the importance of buffalo as a multi-purpose livestock species in the region. Furthermore, the ever increasing density of the livestock in Asia to meet the demand of animal products as part of food, has been a factor of deforestation as per the latest report of Global Forest Coalition, adding up to the rationales for climate change. Therefore, the livestock industry in the coming years, has to balance out the food security, rooting from livestock and environment under the climate-change conditions for the sustainable animal production. Comprehending the biology of thermo-tolerance, under the undeniable consequence of climate change for sustainable livestock production in fact, is gaining importance globally. The water buffaloes (the riverine and the swamp) although distributed densely in the tropical and sub-tropical of Asian continent, are prone to varied range of distress on prolonged exposure to solar radiation- forcing the animals to take up the refuge of multitude of physiological and behavioural changes to survive under the hostile conditions.
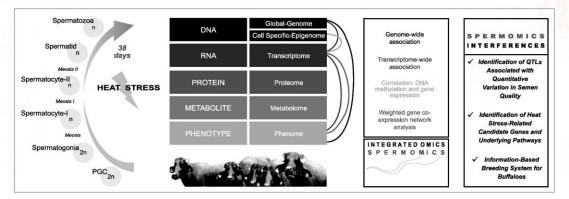
The heat stress is thought to be having a pronounced impact on buffalo reproduction both in males and females, resulting in huge economic losses to the livestock keepers. Females exhibit the anestrus or silent estrus under heat stress, whereas in males, the extended 38-day spermatogenesis cycle is influenced by a number of severe extra-scrotal abiotic factors, which can cause the scrotal temperature to fluctuate, due to a breakdown in the counter-current heat exchange between venous and arterial blood. The aforesaid condition poses thermoregulatory risks, under the hot weather in the semi-tropical belt, where the thermal-humidity index of 70 and above causes testicular hyperthermia in buffalo bulls. The increased

testicular temperature leads to generation of reactive oxygen species (ROS) resulting in cell and DNA damage, apoptosis impacting the sperm functions like capacitation and fertilization as well. The mass artificial insemination practiced Asia-wide is thus influenced, widely by the heat stress, 25 to 45% pregnancy rates reported with frozen semen, when the thermal stress also leads to depressed signs of estrus in females.

This fine line of complexities in thermo-adaptation at the molecular scale inside the animal is a result of complexity at the level of interaction between the livestock and the weather elements. The nexus of molecular changes in response to abiotic stresses, including heat stress, encompasses alterations in RNA transcripts (transcriptomics), proteins (proteomics), metabolites (metabolomics), epigenetic modifications (epigenomics), lipids (lipidomics), carbohydrates (glycomics), and underlying genomic variations (genomics). Furthermore, the interaction between these omics can be investigated using elaborate computational methods such as Genome-Wide Association Analysis (GWAS), Transcription Wide Association Analysis (TWAS), correlation between methylome and transcriptome, and Weighted Gene Co-Expression Network Analysis (WCGNA). With the advancement in the scale of magnification into the system for these molecular changes has increased tremendously, especially with the advent of the II generation of nucleotide sequencing and sophisticated analysis suites. The current portfolio of buffalo genomics resources in sequence read archive (SRA, ncbi.nlm.nih.gov) reflects 910 genomics, 56 epigenomics, 726 transcriptomics submissions, and 5 assemblies. The buffalo "spermomics" has two bioprojects with 219 experiments (SRX#), and out of those only 15 are regarding the abiotic influences submitted till date, this menial reserve indicates urgent need to revisit the buffalo "spermomics" in the context of abiotic stressor particularly the heat-stress, an Asiatic-context. The work carried out on genomics, transcriptomics, and epigenomics of the buffalo spermatozoa in the context of heat stress, is being described here.

Omics and male reproduction

Epigenomics

The epigenetics deals with the transient changes in the genome aided by miRNAs, DNA methylation, chromatin-remodelling etc., which may turn into stable-transgenerational changes in the germ cells in response to abiotic stress. Heat stress during meiosis and the spermiogenesis stage influence global DNA methylation patterns at CpGs, and the virtue of regulatory region may dictate the morphology and kinetics of sperm. Workers have concluded the potential repercussions of transient ambient temperature in shaping the sperm methylome during the protracted phase of spermatogenesis via methylation changes in the promoter region of the calcium channel encoding genes such as *NPTN, ANO1*, and some other sperm structure genes *SEPT6, SPATA*, etc. The global CpG% in the buffalo bulls with poor quality semen during summer season, have also been found to be positively correlated with the scrotal surface and rectal temperature measured during afternoon. The domain lacks inquisitive insight into the other epigenetic changes happening in the various stages of spermatogenesis and various gonadal tissues of buffalo bulls.

There is lot of scope to explore the sperm cell methylome changes occurring due to demthylation and remethylation process involved during the post-fertilization process of embryogenesis. Association of methylome changes due to heat stress with fertility traits will open new avenues to understand the impact of seasons on the quality of semen collected during different seasons.

Transcriptomics

The spatio-temporal degree of involvement of genes varies except for the house-keeping genes, which too are tissue specific. The scope of understanding the transcriptome profile of bulls' reproductive system at various spatial components (testes, seminiferous tubules, sertoli cells, epidydymis, spermatic cord, sperms etc.) represents wide-range of incongruences. Temporal components such as stages of spermatogenesis (PGC, spermatogonial, spermatocyte-I/II, spermatid, and spermatozoa) may reflect upon diverged profile of transcriptome. Therefore, the transcriptomics start-point leaves us with exquisite options rendering to study hypothesis and the target stage of spermatogenesis. So far there are at least three studies published regarding the buffalo bull spermatozoal transcriptomics and Leydig cell transcriptome. The immature to adult Leydig cell transitional-spatial transcriptome the workers have elucidated the key genes involved in the cAMP signaling pathway for testosterone synthesis and role of Leydig cells in buffalo bulls' spermatogenesis. The remaining two studies have elucidated essentially the transcriptome of buffalo bulls with respect to the fertility grading and none of them deals with the temporal transcriptome of the spermatozoa related to seasonal change. Major obstacles identified to work on sperm cells transcriptomics, are the highly fragmented and low quantity of RNA and difficulty in lysing the cells. Workers have to compromise on the RIN value of the RNA isolated from intact sperm cells. Several modified procedures have been published for isolating best quality possible from the sperm cells. Transcriptome data generated on purified sperm cells for Murrah buffalo bulls, two groups, seasonally affected (SA) and seasonally not-affected (SNA) for hot summer and winter, has shown only SNA hot-summer and SNA winter groups showed significant differential gene expression based on gene count (FDR<0.05). Genes related to the developmental process and DNA compaction, motility, mitochondrial oxidative phosphorylation, molecular chaperons, chromatin binding protein, DNA replication, recombination and repair, were highly expressed in SNA hot summer as compared to SNA winter groups, helping the bulls representing two groups to effectively maintain the homeostasis and semen quality, without compromising the cellular function. Based on the significant difference of FPKM values, genes associated with inflammation, protease inhibitors, mitochondrial ribosomal protein were upregulated in SA hot summer as compared to SNA hot summer. Significant number of unclassified transcripts from the transcriptome data identified, which need to be functionally annotated by mapping against well annotated genome assemblies. Selected differentially expressed genes from transcriptome data could be validated by real time PCR also.

Whole genome Sequencing

The whole genome sequence data is the most extensive representation of varied kinds of genomic variations along with the positional information, which could be possibly exploited for selection of animals with improved production and reproduction performance. A single step GWAS analysis of array based genotying data in 8465 semen ejaculates of the Egyptian buffalo, has highlighted SNP-windows explaining the highest genomic variance for trait such as mass motility, % abnormal sperm, sperm livability, concentration and volume. Genes such as *AMMECR1*, *BLM*, *CRTC3*, *DMD*, *GNL3L*, *ITIH6*, and *KCTD8* were identified to be the potential candidates for multiple semen quality traits, whereas novel genes such as *LOC102398394*, *LOC112582129*, *LOC102391626*, *LOC102404920*, and *LOC102397107* for semen volume, mass motility/semen livability/percentage abnormal spermatozoa/concentration, semen livability/ percentage abnormal spermatozoa/concentration, and mass motility/semen livability/percentage abnormal spermatozoa. Other way many of the candidate gene association studies have been conducted, reportiong the association of semen quality with the genes such as *OPN*, *SPAG11B*, *ZNF280BY*, and *AQP7*. Therefore, whole genome sequencing studies in the area of buffalo "spermomics" is hugely lacking in buffalo, and the rare/novel variants identification can still be a 'cache' in the field.

Also there is a need to generate phenomic data on semen quality and fertility traits for association and later validation of potential markers, identified through whole genome sequencing. Recently whole genome sequence data has been generated on buffalo bulls after classifying them into seasonally affected and non-affected, based on the semen quality checked across different seasons. The objective is to identify variations in the key genes and non-coding regions, responsible for altered response to heat stress for quality semen production.

Future prospects

Heat stress has multiple effects on sperm cell function, impacting several pathways and losing the ability to fertilize the ovum. No doubt, NGS tools have added new arsenals to the available resources for understanding and addressing the complex problems of heat stress influencing the reproduction performance of the livestock species, buffalo in particular. A combined approach integrating the management to alleviate the heat stress symptoms and genetics in identifying the target molecules, could definitely be exploited for selecting animals of better reproductive performance. Amalgamating the epigenome, transcriptome and genomic information will help in designing the strategies for identifying the bulls capable of producing quality semen throughout the year, under challenging hot-tropical conditions in buffalo. Exploiting these tools could ensure the production of quality semen in buffalo bulls throughout the seasons.

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Complete genomic landscape reveals significant differentiation of phenotype and productivity in Asian water buffaloes (Bubalus bubalis) following recent and divergent selection

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Abstract

Water buffaloes are one of the most valuable animal genetic resources in the tropical and subtropical climate zones. To identify the genetic determinants of their domestication and productivity, we sequenced and analyzed 470 river or swamp type buffalo genomes from 57 populations. While both types are assumed to have originated from the wild buffalo (Bubalus arnee). However, the swamp type has retained the wild morphology. Notably, most of the river type buffalo populations have a different morphology, but formed cluster with the wild population from Nepal. The genetic diversity has substantially decreased in Italian river buffaloes and Indonesian swamp buffaloes at the western and eastern extremities of the water buffalo distribution range, respectively. However, in the Indonesian swamp buffaloes purifying selection prevented the accumulation of potentially harmful loss-of-function variants. Several genes those have evolved rapidly (e.g., *GKAP1*) by differential selection in both river and swamp buffaloes are involved in reproduction. Genes related to milk production performance and coat color have undergone a strong selection in dairy river buffaloes, either via a soft (for the dairy gene *CSN2*) or via a hard (for the coat color gene *MC1R*) genetic sweep. By integrating the selection sweep and single-cell RNA-seq data we have located luminal cells as the key cell type that underlies artificial selection for milk production and revealed higher developmental potential in the dairy breeds. These findings show how artificial selection has driven divergence, performance and changes in morphology in domestic water buffalo.

Keywords: Buffalo, population structure, selection signature, *CSN2*, *MC1R*.

Detection of polymorphisms in *FASN*, *DGAT1*, and *PPARGC1A* genes and their association with milk yield and composition traits in river buffalo of Bangladesh

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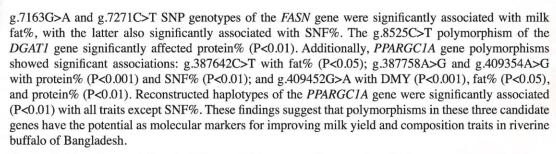
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Abstract

This study aimed to identify SNPs in the intron, exon, and UTR regions of the *FASN*, *DGAT1*, and *PPARGC1A* genes, and to investigate their possible association with milk yield and composition traits in riverine buffalo of Bangladesh. A total of 150 DNA samples from riverine buffalo were used for PCR amplification with five pairs of primers, followed by association studies using a generalized linear model in R. SNP genotyping was performed by direct sequencing of the respective amplicon. Traits analyzed included DMY, fat%, protein%, and SNF%. This study identified 8 SNPs in *FASN* (g.7163G>A and g.7271C>T), *DGAT1* (g.7809C>T and g.8525C>T) and *PPARGC1A* (g.387642C>T, g.387758A>G, g.409354A>G, and g.409452G>A). Genotypic and allelic frequencies differed significantly for each SNP genotype and did not follow the Hardy-Weinberg principle (P<0.01 or P<0.01) in most cases. The

g.7163G>A and g.7271C>T SNP genotypes of the *FASN* gene were significantly associated with milk fat%, with the latter also significantly associated with SNF%. The g.8525C>T polymorphism of the *DGAT1* gene significantly affected protein% (P<0.01). Additionally, *PPARGC1A* gene polymorphisms showed significant associations: g.387642C>T with fat% (P<0.05); g.387758A>G and g.409354A>G with protein% (P<0.001) and SNF% (P<0.01); and g.409452G>A with DMY (P<0.001), fat% (P<0.05), and protein% (P<0.01). Reconstructed haplotypes of the *PPARGC1A* gene were significantly associated (P<0.01) with all traits except SNF%. These findings suggest that polymorphisms in these three candidate genes have the potential as molecular markers for improving milk yield and composition traits in riverine buffalo of Bangladesh.

Keywords: Genetic association, buffalo, candidate gene, milk properties, SNP.

Association between microsatellite markers, milk yield traits and milk composition in murrah crossbreed buffalo

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Abstract

The majorities of commercially significant animal production features are quantitative and complicated such as dairy buffalo milk output and composition. Many genetic regions are responsible for these features. Quantitative Trait Loci (QTL) is genomic area that may be identified by examining their relation to known molecular markers, such as microsatellites. Microsatellites are highly polymorphic markers scattered throughout the entire genome. They have helped in discovering the QTL regulating milk output in numerous dairy livestock, including buffaloes. As a result, the potential for MAS and recently GS adoption would arise. The molecular mechanisms underpinning genetic variability in milk production features in Murrah buffaloes were better understood thanks to this study. In the Murrah crossbred buffaloes, we investigated variation in eight microsatellite markers and found that they were associated with milk production attributes. National Livestock Breeding Office, Lamapatan, Kaski provided multiple year phenotypic data of each individual and permitted us to take blood samples of each buffalo from which the phenotypic data were taken. PROMEGA extraction kits were used to get the g-DNA. After thermocycling each sample with each marker, both Vertical Polyacrylamide Gel Electrophoresis and Agarose gel electrophoresis were done, with the exception of marker BM143, which exhibited satisfactory amplification. The allele frequencies, divergence from the Hardy-Weinberg percentage, effective number of alleles, observed and expected heterozygosity and fixation index across each locus were all calculated using the GenAlex software tool. Also, the association between the milk production trait with non-genetic factors as well as markers was determined via Linear model in R programming. Total of 37 alleles were detected across the studied loci with mean observed and effective allele as 5.286 and 2.749. The mean observed heterozygosity was 0.380. Association analysis showed that except ETH2, all the markers were significantly associated (P<0.01) with milk yield traits. The milk composition as Fat% and Protein% showed association with all the markers (P<0.01).

Keywords: QTL, Microsatellites, Milk yield and Composition, Phenotyping, Genotyping, Vertical PAGE.

ORAL PRESENTATION

Melatonin supplementation improves the quality of inferior oocytes and embryonic development by reducing oxidative stress

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Abstract

The buffalo (*Bubalus bubalis*) is crucial to the agricultural economies of many developing nations through providing milk, meat, and draught power. Animal cloning holds significant promise for accelerating the reproduction of superior buffaloes and preserving their valuable genetic material. However, the success of animal cloning is often hindered by the poor quality of oocytes, closely linked to their reprogramaming ability. Due to their poor quality, about half of the cumulus-oocyte complexes (COCs) referred as inferior oocytes (IO) was discarded in many laboratories. To address this issue, we investigated the effect of melatonin treatment during the in vitro maturation (IVM) of buffalo oocytes and subsequent embryo development. Melatonin, a hormone primarily secreted by the pineal gland, has anti-inflammatory and antioxidant properties, scavenging reactive oxygen and nitrogen species, boosting antioxidant defences, and inhibiting the transcription factors of pro-inflammatory cytokines. To reach our goal, buffalo oocytes were grouped as superior (A+B) and inferior (C+D) oocytes and were supplemented with single dose of melatonin (10-9M). The results indicate that melatonin (10-9M) supplementation significantly (P≤0.05) enhances IO maturation, reduces oxidative stress by lowering ROS levels, and improves mitochondrial function by increasing GSH levels. Additionally, melatonin treatment increases the total cell number and decreases the expression of BAX, caspase 3, and caspase 9 genes, promoting cloned blastocyst formation rates. Moreover, 10-9M melatonin administration enhances H3K9 acetylation and reduces H3K27me3 methylation in cloned blastocysts. In conclusion, 10-9M melatonin supplementation during IVM may improve the quality and increase the blastocyst formation rate of buffalo cloned embryos, advancing the efficacy of cloning procedures in buffalo species.

Keywords: Melatonin, cumulus-oocyte complexes, ROS, mitochondrial function.

Genomic analysis reveals the association of *KIT* and *MITF* with white spotting in swamp buffaloes

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Abstract

Swamp-type buffaloes with varying degrees of white spotting are found exclusively in Indonesia, where spotted buffalo bulls are highly valued according to Torajan customs. The white spotting is caused by the absence of melanocytes. However, the genetic variants that cause this phenotype have not been fully characterized. The objective of this study was to identify the genomic regions and variants responsible for this unique coat-color pattern.

The genome-wide association study (GWAS) and selection signature analysis were conducted using whole-genome sequencing data from 28 solid colored and 39 spotted buffaloes. Additionally, eleven genes associated with white spotting were analyzed through a candidate gene approach. The variants' effects were annotated using SnpEff. Fisher's exact test was utilized to confirm the association between variants and coat color patterns. PCR and mutation frequency analysis in other buffalo populations were employed to validate candidate mutations.

GWAS and selection signature analysis identified *MITF* as a key gene, while *KIT* was found to be involved in the development of this phenotype by a candidate gene approach. In addition to the previously reported nonsense mutation (c.649C>T) and splice donor mutation (c.1179+2T>A) in *MITF*, a nonsense mutation (c.2028T>A) in *KIT* was identified. These three mutations were located in the genomic regions that were highly conserved exclusively in Indonesian swamp buffaloes and they accounted largely (95%) for the manifestation of white spotting. Last but not the least, *ADAMTS20* and *TWIST2* may also contribute to the diversification of this coat-color pattern.

The alternative mutations identified in this study affect, at least partially and independently, the development of melanocytes. The presence and persistence of such mutations might have significant financial and social value of spotted buffaloes used in historical Rambu Solo ceremony in Indonesia. Several *de novo* spontaneous mutations have therefore been favored by traditional breeding for the spotted buffaloes.

Keywords: White spotting, swamp buffalo, *MITF*, *KIT*, whole-genome sequencing.

A multi-tissue gene expression atlas of water buffalo (*Bubalus bubalis*) reveals transcriptome conservation between buffalo and cattle

Jingfang Si[1], Dongmei Dai[1], Kun Li[1], Lingzhao Fang[2] and Yi Zhang[1]*
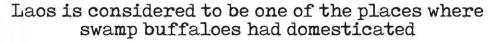
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Abstract

Gene expression atlases have been widely used to investigate gene expression in different tissues, cell types, and developmental stages, which can help improve the functional annotation of the genome and understanding of the molecular mechanisms underlying different tissues and complex biological processes. In this study, we generated 73 transcriptomic data of water buffalo, which were integrated with publicly available data in this species, yielding a large dataset of 355 samples representing 20 major tissue categories. We established a multi-tissue gene expression atlas of water buffalo. Furthermore, by comparing them with 4866 cattle transcriptomic data from the cattle genotype–tissue expression atlas (CattleGTEx), we found that the transcriptomes of the two species exhibited conservation in their overall gene expression patterns, tissue-specific gene expression and house-keeping gene expression. We further identified conserved and divergent expression genes between the two species, with the largest number of differentially expressed genes found in the skin, which may be related to structural and functional differences in the skin of the two species. This work provides a source of functional annotation of the buffalo genome and lays the foundations for future genetic and evolutionary studies in water buffalo.

Keywords: RNA-seq, gene expression atlas, tissue-specific gene, comparative transcriptome.

POSTER PRESENTATION

Laos is considered to be one of the places where swamp buffaloes had domesticated

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Abstract

The purpose of this study was to clarify the genetic characteristics of Lao native buffaloes and to clarify the place of domestication of swamp buffaloes including Laos. In this purpose, microsatellite DNA, mitochondrial (mt) DNA, and ZFY genes were analyzed. As a result of the microsatellite DNA study through admixture analysis revealed three distinct groups in K=3 that included buffalo populations from, Laos and southern Vietnam, Indonesia, and other Southeast Asian countries. At K=7, It was revealed that the genetic structure of Laos (Champasack, Attapeu, and Huaphanh populations) buffalo populations had a clear differentiation from other Southeast Asian countries. The sequence of the 422 bp D-loop of mtDNA was determined. Using these data, a median-joining network was drawn, and the results showed Laos had two different maternal ancestral lineages. To clarify the genetic relationships among swamp buffalo populations in Southeast Asian countries, a neighbor-joining phylogenetic tree was drawn. The swamp buffaloes in mainland countries were significantly separated from island countries. There were two groups in mainland countries: a group from Laos and Thailand and the another group included others. A 655bp sequence of the ZFY gene on the Y chromosome of swamp buffaloes of Far East and river buffaloes of Bangladesh were analyzed. Polymorphisms were found at base positions 192 and 641. The swamp buffaloes had haplotypes of G, G and A, G, respectively, while the river buffaloes had only the haplotype of G, C. This result revealed that there were two different paternal ancestors in Laos. These results showed that the native buffaloes in Laos have unique genetic characteristics compared to other Southeast Asian countries. Therefore, it is strongly suggested that one of the domestication places for the swamp buffaloes was in Laos.

Keywords: Lao indigenous buffaloes, microsatellite DNA, mtDNA, ZFY gene, domestication.

Whole-genome sequencing reveals genetic structure and adaptive genes in Nepalese buffalo breeds

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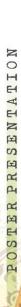
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Abstract

Indigenous buffaloes, as one of the important livestock species to the country's economy, are the lifeline of livelihood in Nepal. They are distributed across various geographical regions of the country and have adapted to multiple feeding and management conditions. The larger group of these native buffalo breeds are present in narrow and stiff hilly terrains. Their dispersal indicates a possible environmental adaptation mechanism, which is crucial for the conservation of these breeds. We utilized whole-genome sequencing (WGS) to explore the genetic diversity, population structure, and selection signatures of Nepalese indigenous buffaloes. We compared 66 whole-genome sequences with 118 publicly available sequences from six river and five swamp buffalo breeds. Genomic diversity parameters indicated

POSTER PRESENTATION

genetic variability level in the Nepalese buffaloes comparable to those of Indian breeds; and across all Nepalese indigenous buffalo populations, the Terai (NPL_BT) breed had the highest values of minor allele frequency (MAF: 0.2424), nucleotide diversity (π: 0.00275348), observed heterozygosity (H_O: 0.315626), and expected heterozygosity (HE: 0.333463). Additionally, population genetic structure analysis by Principal component analysis (PCA), admixture, and neighbor-joining (NJ) tree revealed distinct geography-mediated genetic differentiation among the Nepalese and other breeds. For further analysis of this differentiation, we used locus-specific branch length analysis (LSBL) for the genome-wide scan, which revealed a list of potentially selected genes in Lime and Parkote breeds (collectively as NPL_LP) inhabiting the hilly region. Through gene ontology (GO) analysis, we discovered that many of these GO terms were associated with cardiac function regulation. Furthermore, complementary analyses of local selection signatures, tissue expression profiles, and haplotype differences identified candidate genes, including KCNE1, CSF1R, and PDGFRB, related to the regulation of cardiac and pulmonary functions. This study is a comprehensive WGS-based genetic analysis of the native Nepalese buffalo breeds. Our study suggested that the Nepalese "hilly" buffaloes, especially the Lime and Parkote breeds, have undergone some characteristic genetic changes and evolved increased cardiac and pulmonary function for their adaptation to the steep hilly terrains of the country.

Keywords: Whole-genome sequencing, buffalo, genetic diversity, population structure, selection signatures.

Exploring the genomic diversity using whole genome sequence data of water buffalo populations in Bangladesh and China

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Abstract

This study was performed using whole genome sequence data to investigate the genetic diversity and population structure of the water buffalo population in China and Bangladesh. Genomic DNA was extracted from whole blood samples of 92 unrelated water buffaloes (52 river type and 40 swamp type) using the phenol chloroform method, and paired-end libraries were constructed for each individual and sequenced using the Illumina HiSeq X Ten platform. Genomic annotation of the polymorphic sites screening the location of those SNPs indicated that most of the SNPs existed in the intergenic region (48.50%) or in the intron region (38.03%), while the exon contains only 0.98% of the total SNPs. Ho and He value ranged from 0.276 to 0.340 and 0.300 to 0.353, respectively in different buffalo populations. Among water buffalo populations, the value of FIS ranged from 0.036 (SWP-CHN) to 0.132 (IND-MR), and were statistically non- significant. ADMIXTURE analysis provided a clear pattern of geographical distribution among those buffalo populations. In K=4, BGD-S population showed clear signs of different ancestries that evolved by the hybridization process and were more similar with riverine ancestry. In the result of PC1 and PC2, BGD-NE population and the SWP-CHN population stranded closer. As expected, the result of NJ tree indicates two different cluster groups for river type and swamp type populations. According to the result from the total ROH length, BGD-MR has the highest proportion of ROH, followed by BGD-NW, BGD-S and BGD-NE population. BGD-S population had the highest nucleotide diversity level (value) among all the populations that is the similar finding with linkage disequilibrium (LD) decay analysis (you didn't show the results on LD analysis). Give one sentence here on concluding remarks.

Keywords: Water buffalo, WGS, genetic diversity, population structure.

POSTER PRESENTATION

Effect of single-step commercial media on the production of zona-free embryos (cloned and parthenogenetic) of buffaloes
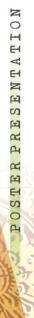
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Abstract

Numerous embryo culture media are used for the production of cloned and IVF embryos in farm animals. Previously, we used RVCL media for buffalo embryo production, but this media has now been discontinued. Therefore, we conducted a study to identify the best suitable media for buffalo zona-free embryo production. In the present study, we used four single-step continuous embryo culture media: Vitrogen, RVCL, IVF-Bioscience (IVF-BO), and GM-501. In the first experiment, we examined the effect of these media on the production of zona-free parthenogenetic embryos. We achieved a blastocyst production rate (%) of 37.67 ± 12.44, 31.40 ± 3.29, 37.77 ± 4.47, and 37.80 ± 5.88 for RVCL, Vitrogen, GM-501, and IVF-BO, respectively. These results highlight that the RVCL, GM-501, and IVF-BO media achieved the highest blastocyst production rates, while Vitrogen resulted in the lowest rate among the media tested. Additionally, embryos cultured in Vitrogen media tended to attach to the surface of the culture dish, indicating that Vitrogen is not suitable for zona-free embryo production. Based on these results, we further compared GM-501 and RVCL media for the production of cloned and IVF embryos. The GM-501 medium resulted in a cloned blastocyst production rate of 39.24 ± 4.73, while the RVCL medium achieved a rate of 39.78 ± 3.48. We also analyzed the total cell number of the produced blastocysts and found no significant difference between GM-501 and RVCL. This study helps identify suitable media for the production of zona-free embryos. We recommend using GM-501 or IVF-BO media for future applications in buffalo embryo production.

Keywords: Buffalo, embryos, media, cloned, IVF, parthenogenetic.

POSTER PRESENTATION

SCIENTIFIC
SESSION

HEALTH
AND
ADAPTABILITY

Optimizing buffalo health: understanding the interplay with adaptability

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Abstract

Buffalo (*Bubalus bubalis*) are renowned for their adaptability, thriving in diverse environments and management systems. However, their health is crucial for optimal productivity, welfare, and sustainability. This presentation delves into the complex relationship between buffalo health and adaptability, exploring how their adaptability influences their health and vice versa. We discuss the impact of environmental factors, nutrition, and management practices on buffalo health, highlighting the importance of understanding their adaptability in response to stressors, diseases, and nutritional challenges. Following key areas are identified for improving buffalo health:

- Nutritional strategies to enhance immune function and disease resistance

- Effective parasite control and disease management

- Optimal husbandry practices to minimize stress and promote welfare

- Breeding programs to enhance genetic resilience and adaptability

By considering the interplay between buffalo health and adaptability, we can develop targeted interventions to optimize their health, productivity, and sustainability, while harnessing their remarkable adaptability to thrive in diverse settings.

Keywords: Health, adaptability, productivity, sustainability, welfare.

Prologue

Buffaloes have significant global importance due to their contributions to food security and economic growth through high-quality milk, meat, and hide and supporting the livelihoods of millions of people worldwide. They contribute to rural employment, income generation, and poverty alleviation, especially in developing countries. Buffaloes are also used for draft purposes, facilitating agricultural activities and transportation in many developing countries. Buffaloes hold cultural and religious importance in many societies, featuring in festivals, traditions, and symbolism. As a hardy species, buffaloes can adapt to challenging environments, making them valuable for sustainable agriculture and climate resilience. Buffalo conservation and sustainable management, being a vital component of global food systems, economies, and cultures, is essential.

Globally, buffalo population is approximately 200 million, with about 90% in Asia. The top buffalo-rearing countries are India (more than 50% of global population), China, Pakistan, Brazil, Italy, Egypt, Nepal, Philippines, Thailand and Vietnam besides Bangladesh, Sri Lanka, Myanmar, Indonesia, Malaysia, Turkey, Greece, Bulgaria and Romania among others.

Buffaloes are an integral part of India's agricultural landscape and play a vital role in India's livestock sector, significantly contributing to the country's GDP. They are the primary source of milk and dairy products, accounting for over 50% of India's total milk production despite the fact that the buffalo population in India is about a third of the total large ruminant population. At 109.85 million (20th Livestock Census 2019), it is the largest in the world. Their milk production contributes substantially to the dairy industry's growth. Additionally, buffaloes are used for draft purposes, providing power for agricultural activities and transportation in rural areas. The buffalo-based livestock sector also provides employment and livelihood opportunities for millions of rural households, making it a crucial component of India's rural economy.

Impact of Climate Change on Buffalo Health

Climate change is a pressing global issue characterized by significant changes in weather patterns, increased frequency of extreme weather events, and rising global temperatures. The global average temperature has increased by about 1.5⬚C since the pre-industrial era, with 2023 being one of the hottest years on record. There is an increased frequency and intensity of extreme weather events such as hurricanes, floods, droughts, and heatwaves. Polar ice caps and glaciers are melting at unprecedented rates, contributing to rising sea levels. Oceans are warming and becoming more acidic due to increased carbon dioxide absorption, affecting marine ecosystems. Changes in rainfall patterns are leading to more severe droughts in some regions and increased flooding in others.

Climate change has far-reaching effects on animal health, affecting all livestock with no exception to buffaloes. Increased temperatures can cause heat stress in animals, leading to reduced feed intake, lower productivity (milk/meat production), reproductive performance, immune function and even death in extreme cases. Climate change can alter disease dynamics, by influencing the spread and emergence of diseases. Warmer temperatures and altered precipitation patterns can expand the range of vectors such as ticks, mosquitoes, and flies, increasing the incidence of vector-borne diseases (e.g., anaplasmosis). Droughts and altered precipitation can reduce the availability of water and forage, leading to malnutrition and dehydration. Poor nutrition weakens animals' immune systems, making them more susceptible to diseases. Extreme temperatures and environmental stress can negatively impact the reproductive cycles of buffaloes, leading to lower calving rates and increased neonatal mortality. Animals may also alter their behaviour in response to changing environmental conditions, such as foraging habits, and social structures. These changes can impact their health and survival. Addressing these challenges requires adaptive management strategies, improved monitoring of animal health, and proactive measures to mitigate the effects of climate change on animal populations.

Buffalo Health

The health status of buffaloes varies across countries due to differences in environmental conditions, management practices, and disease prevalence. The buffalo, being a bovine, is susceptible to most of the diseases and parasites that afflict cattle. Although the reasons are not specifically known, the effect of diseases on the buffalo and its productivity is often less deleterious than on cattle in the same ecosystem. It faces several common challenges, including infectious diseases like FMD, HS, brucellosis, and various parasitic infestations. In India, like many other countries, the major health challenges due to climatic conditions and disease management practices include Foot and Mouth Disease (FMD), Hemorrhagic Septicemia (HS), Brucellosis and Parasitic Infestations both internal parasites (e.g., helminths) and external parasites (e.g., ticks), impacting their health and productivity. In Pakistan, health challenges are similar to those in India, with some regional variations where Buffalo Pox, Theileriosis and Mastitis also gain higher significance besides FMD and HS. Buffaloes in China are primarily used for draught power, milk, and meat. Though health management practices have improved, some diseases like FMD, Tuberculosis, Brucellosis and parasitic infestations remain problematic. The environmental stress and diseases pose big challenges to buffalo health in Egypt where Lumpy Skin Disease is also reported as an issue in buffaloes. In Brazil, tick-borne diseases including anaplasmosis and babesiosis, impact productivity and health besides other common issues faced by other countries. Southeast Asia (Thailand, Philippines, and Vietnam) has many similar issues including swamp buffalo dermatitis. Europe, especially Italy, is known for its high-quality buffalo mozzarella cheese. Buffaloes there are reared in intensive systems with good health management practices, however, diseases like brucellosis and mastitis, are still reported besides parasitic and respiratory diseases. In the broadest sense it seems that, subject to local and regional variations, the susceptibility of the buffalo to this disease increases from western to eastern Asia.

Effective health management practices, including regular vaccinations, parasite control, and improved husbandry, are essential to address these issues and improve the overall health and productivity of buffaloes globally.

The health of buffaloes is significantly influenced by a combination of environmental factors, nutrition,

and management practices. Understanding these impacts is crucial for optimizing their health and leveraging their adaptability in response to various stressors, diseases, and nutritional challenges.

Environmental factors significantly impact buffalo health, with climate, water availability, and habitat quality being key. Extreme weather can cause heat stress or cold-related challenges, while water scarcity leads to dehydration and reduced productivity. Nutrition is vital, requiring a balanced diet and high-quality forage to prevent malnutrition and support growth. Effective management practices, including regular health check-ups, selective breeding, and proper shelter, are essential for disease prevention and overall well-being.

Understanding Adaptability

Understanding buffalo adaptability is crucial in managing their response to stressors, diseases, and nutritional challenges. Adaptable buffaloes are better equipped to handle environmental stressors such as temperature extremes and habitat changes. Recognizing signs of stress and implementing measures to alleviate it, such as providing shade and water during hot weather, can mitigate adverse health effects. Buffaloes that are well-adapted to their environment often have enhanced disease resistance. Monitoring for common diseases and implementing preventative measures, such as vaccinations and biosecurity practices, help maintain herd health. In environments where nutritional resources are variable, understanding the adaptability of buffaloes helps in developing feeding strategies that ensure consistent nutritional intake. This includes rotational grazing, supplemental feeding during lean periods, and ensuring access to diverse forage. Thus, environmental factors, nutrition, and management practices collectively influence buffalo health. By understanding and leveraging their adaptability, health outcomes can be optimized to enhance disease resistance, and manage nutritional challenges effectively. This holistic approach ensures the well-being and productivity of buffalo populations, supporting their sustainable management in diverse environments.

Relationship between buffalo health and adaptability and Interdependent Dynamics Buffalo Adaptability

Buffaloes are highly adaptable animals, thriving in diverse environments due to their environmental tolerance, dietary flexibility, and physiological resilience. They can survive in tropical, subtropical, and semi-arid areas, efficiently managing temperature fluctuations, humidity, and water scarcity. Their varied diet, which includes grasses, aquatic plants, and crop residues, allows them to adapt to different ecological niches. Buffaloes possess robust physiological mechanisms, such as efficient thermoregulation and the ability to endure long periods without water, enabling them to cope with environmental stressors. This adaptability enhances their health by improving disease resistance, ensuring nutritional balance, and reducing stress levels. In turn, healthy buffaloes have higher reproductive success, stronger offspring, and longer lifespans, which further enhance their adaptability. The relationship between health and adaptability is cyclical and interdependent, with adaptive traits supporting health and good health enabling effective adaptation. This dynamic interplay ensures the resilience and survival of buffalo populations across varied ecological contexts.

Strategies and targeted interventions: The way forward

Some key areas for improving buffalo health may include nutritional strategies to enhance immune function and disease resistance, effective parasite control and disease management, optimal husbandry practices to minimize stress and promote welfare and breeding programs to enhance genetic resilience and adaptability. Improving buffalo health requires a comprehensive approach that encompasses these aspects along with targeted breeding programs.
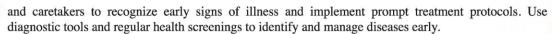
Health Management Interventions

Effective Parasite Control and Disease Management

Regular Health Monitoring: Implement regular health check-ups to monitor for signs of diseases and parasites. Early detection allows for prompt treatment and prevents the spread of infections. Train staff

and caretakers to recognize early signs of illness and implement prompt treatment protocols. Use diagnostic tools and regular health screenings to identify and manage diseases early.

* *Integrated Parasite Control:* Implement an integrated parasite management program that includes rotational grazing, regular deworming based on fecal egg counts, and biological control methods (e.g., introducing dung beetles). Use anthelmintics strategically to control internal parasites. Rotating anthelmintic classes and administering treatments based on fecal egg counts can prevent resistance development and ensure effective parasite control.

* *Vaccination Programs:* Establish and adhere to comprehensive vaccination schedules for common infectious diseases such as foot-and-mouth disease, brucellosis, and anthrax to protect buffaloes from these infections. Ensure all animals are vaccinated according to veterinary guidelines. Vaccinations are a critical component of preventive healthcare.

* *Biosecurity Measures:* Enforce stringent biosecurity practices to prevent and minimize the introduction and spread of diseases. This includes quarantine protocols for new animals, controlling visitor access, and maintaining hygiene in housing and feeding areas for cleaner facilities.
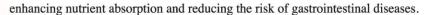
Breeding Programs to Enhance Genetic Resilience and Adaptability

* *Selective Breeding:* Focus on selective breeding to enhance desirable traits such as high milk yield, disease resistance, environmental adaptability, and reproductive efficiency. Choosing animals with proven resilience to local conditions can improve the overall health and productivity of the herd. Use performance records and genetic testing to inform breeding decisions.

* *Conservation of Indigenous Breeds:* Protect and promote indigenous buffalo breeds that are naturally adapted to local conditions. These breeds often possess valuable traits for resilience and productivity in specific environments.

* *Genetic Diversity:* Maintain genetic diversity within the herd to prevent inbreeding and ensure a broad genetic base. Genetic diversity contributes to the adaptability and long-term sustainability of the population. Cautiously introduce crossbreeding programs, as per requirement, to combine the strengths of different buffalo breeds, enhancing overall genetic diversity and adaptability to various environmental conditions.

* *Use of Modern Breeding Technologies:* Employ modern breeding technologies/ assisted reproductive technologies, such as artificial insemination and embryo transfer/IVF, to introduce desirable traits and improve genetic quality. These techniques can accelerate the genetic improvement and spread desirable traits more widely within the herd for development of resilient and adaptable buffalo populations.

* *Performance Monitoring:* Implement systems to monitor and record performance data, including growth rates, milk production, and disease incidence. Analyzing this data helps in making informed breeding decisions and tracking the success of breeding programs.

Nutritional Strategies to Enhance Immune Function and Disease Resistance

* *Balanced Diet:* Ensure that buffaloes receive a balanced diet containing the right proportions of carbohydrates, proteins, fats, vitamins, and minerals. Adequate nutrition supports a robust immune system, making buffaloes more resilient to diseases. Develop customized feeding programs tailored to the specific needs of buffaloes at different life stages (calves, lactating females, working males). This ensures they receive the appropriate nutrients for growth, milk production, and overall health.

* *Micronutrient Supplementation:* Specific micronutrients, such as zinc, selenium, and vitamins A, D, and E, play crucial roles in immune function. Supplementing these nutrients can enhance disease resistance and overall health. Thus, provide supplemental feeds during seasons when natural forage is scarce or of poor quality. This can include high-protein concentrates, mineral blocks, and vitamin supplements to maintain health and productivity.

* *Probiotics and Prebiotics:* Adding probiotics and prebiotics to the diet can improve gut health, which is closely linked to immune function. These supplements help maintain a healthy balance of gut microbiota,

enhancing nutrient absorption and reducing the risk of gastrointestinal diseases.

High-Quality Forage: Providing high-quality forage ensures that buffaloes receive adequate fiber and essential nutrients. Regular assessment of forage quality and supplementation during periods of low forage availability can prevent malnutrition and associated health issues. Integrate high-quality forage crops such as alfalfa, clover, and legumes into grazing systems. These crops can enhance the nutritional value of the diet and also improve soil health through nitrogen fixation.

Silage and Hay: Store silage and hay to ensure a steady supply of quality feed during the dry season or periods of low forage availability. This helps maintain consistent nutrition and body condition throughout the year.

Optimal Husbandry Practices to Minimize Stress and Promote Welfare

* *Adequate Housing:* Provide well-designed, ventilated, clean, and spacious shelters that protects buffaloes from extreme weather conditions and offers sufficient space for movement, resting and for natural behaviours. Proper housing reduces stress and the risk of injuries.

* *Clean Water Supply:* Adequate hydration is essential for health, productivity, and stress reduction. Therefore, ensure a consistent supply of clean and fresh water at all times. This includes regular maintenance of water sources and provision of water troughs that are easily accessible to all animals.

Gentle, Low-Stress Handling: Implement low-stress handling techniques to minimize fear and anxiety during interactions including during management procedures. Training staff in animal behaviour and humane animal handling practices can significantly improve welfare and productivity while reducing stress-related health issues.

Environmental Enrichment: Incorporate environmental enrichment strategies, such as providing varied foraging opportunities and social interactions, and play structures to enhance mental well-being and reduce stress.

Sustainability Interventions
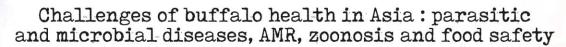
* *Rotational Grazing:* Implement rotational grazing systems to prevent overgrazing, promote pasture regrowth, and improve soil health. This practice enhances forage quality and availability over time.

Agroforestry Systems: Integrate agroforestry practices, such as planting trees and shrubs within grazing areas, to provide shade, improve soil fertility, and offer additional forage resources.

* *Water Harvesting:* Develop water harvesting systems to collect and store rainwater for use during dry periods. This ensures a consistent water supply and reduces dependence on external water sources.

* *Waste Management:* Implement effective waste management practices to reduce environmental pollution and promote sustainability. Use manure as a fertilizer to improve soil health and reduce the need for chemical inputs.

By focusing on these key areas - nutritional strategies, parasite control and disease management, optimal husbandry practices, and targeted breeding programs - buffalo health can be significantly improved. This comprehensive approach ensures that buffaloes are well-nourished, protected from diseases and parasites, experience minimal stress, and possess the genetic strength to thrive in diverse environments. Optimizing the health, productivity, and sustainability of buffaloes while leveraging their natural adaptability and resilience involves targeted interventions across nutrition, health management, breeding, and husbandry practices. These strategies ensure buffaloes thrive in diverse settings while contributing to sustainable agricultural practices.

Challenges of buffalo health in Asia : parasitic and microbial diseases, AMR, zoonosis and food safety

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Abstract

Buffalo is regarded as the black gold of Asia due to its outstanding quality of milk and meat. There are limited health surveillance and monitoring system in relation to housing, breeding, de-worming, vaccination, animal identification and record-keeping. Factors like genetic makeup, poor nutritional and management practices, environmental stress, climate changes, diseases are the major buffalo health challenges in Asia. Diverse agro-climatic conditions, animal husbandry practices and pasture management are influencing the incidence and severity of various diseases of buffaloes. Buffaloes, like other domestic animals are exposed to parasitic, microbial infections, toxic agents, and even dietary deficiencies. Both vector-borne and endo-parasitic infestations is a persistent problem for buffalo health and increasing antimicrobial and anthelmintic resistance is posing an added challenge to control parasites. Buffaloes are more susceptible to Hemorrhagic Septicemia (HS) and die in larger number compared to cattle and prolong the survival of HS organism and tends to spread more rapidly. Most of the non-parasitic enteritis caused by *E. coli* (62.5%) and *Salmonella* sp. (29.16%), clinical (23.68%) and subclinical (31.57%) mastitis remained as major challenge. Unfortunately, buffalo play a major role in the maintenance and transmission of foot and mouth disease (FMD) as permanent carriers. A number of zoonotic and food-borne parasitic and microbial diseases affect the human wellbeing in a diverse transmission dynamic due to food habit and sociocultural practices. It has been reported that 70% farmers vaccinate their buffalo, whereas 66 % vaccination was done for FMD, 24 % for Black quarter (BQ) and 20% for HS, respectively. However, the vaccination coverage was found to be very low. It is important to assess vaccine efficacy, develop a strategy to improve coverage and conduct sero-surveillance to determine coverage and duration of immunity of bacterial and viral diseases. The limited manpower and lack of transport restricts the ability of the veterinary surgeon to respond to all reported cases. Amid lax monitoring by the veterinary authorities and lack of veterinary officers opt for antibiotics because of their easy availability in pharmacies and ability to yield quick results. These events causes unexpected health hazard and drug resistance. Adaptation level of technologies should be ensured by creating public awareness and providing door-step service to the buffalo farmers. To improve buffalo health, disease surveillance, a regional professional buffalo health network should be developed in Asia. Livestock Disease Information System (LDIS),

recently developed with the support from FAO ECTAD for reporting livestock diseases in Bangladesh. Metagenomics of gut microbiota and metabolomics of buffalo should be a choice for better health predictors in future. With the rapid progress of technology and changing climates, precision livestock farming (PLF) incorporates artificial intelligence technology to automatically monitor and manage buffalo health to assists large farms to be economically and environmentally sustainable although, the outweigh cost of PLF still is a question. Buffalo health management in Asia is very challenging because it must address related all issues in socioeconomic and natural approaches on various aspects of ecosystems, resources, natural hazards, climate change, diseases and their impacts, effective response by the concerned authority. The most important is to have interlinked among the government and non-government authorities with local buffalo farmers in any approaches that could ensure buffalo health and sustainability of buffalo farming in this region.

Keywords: Buffalo health, Asia, parasites, microbes, AMR, zoonosis and food-safety.

Introduction

Asian buffaloes dominate the world population, represents about 97% of the 166 million water buffalo populations are found in Asian countries; while the African countries comprises of 2.12%, the South
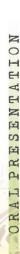
American and European countries comprises of 0.84 and 0.15% of the world buffalo population, respectively (Faruque et al., 1990). Buffalo is popularly known as "black gold" in South Asia. The total buffalo population in Bangladesh is 1.457 million, mostly of them are riverine type buffalo but there are also present some swamp type, of which the coastal region possess more than 40% (DLS, 2019; Mittal et al., 2019). It has been reported that buffalo milk production in South Asian countries representing about 96.05 % of Asia and 93.19 % of the world's buffalo milk production in which both India and Pakistan share 67.99% and 23.96% of the world buffalo milk production, respectively. About 71.4% of world buffalo meat is produced in South Asian countries (Hamid et al., 2016). The husbandry and production systems of buffaloes vary depending upon the topography and vegetation patterns of the country. Coastal Zone is the region where land, ocean and atmosphere interact with each other. Around 35 million people, representing 29% of the world population, live in the coastal zone (Ahmad, 2019). Coastal zone of Bangladesh consists of 19 districts that are Jashore, Narail, Gopalganj, Shariatpur, Chandpur, Satkhira, Khulna, Bagerhat, Pirozpur, Jhalakati, Barguna, Barisal, Patuakhali, Bhola, Lakshmipur, Noakhali, Feni, Chattogram and Cox's Bazar (Ahmad, 2019). It has been showed that deeply flooded area would increase by 29% from the base year 2000. The total amount of salinity affected land in Bangladesh was 83.3 million hectares in 1973, which had been increased to 105.6 million hectares in 2009 and continuing to increase (Mahmuduzzaman et al., 2014). Depending on the geographic features, coastal zone of Bangladesh consists of three parts; Eastern zone, Central zone and Western zone (Sarwar, 2005). It is dynamic and diverse in nature being continually attacked by cyclones, sea level rise, storm surge which have caused terrible impacts on buffalo health in low lying coastal area in the recent years. Buffaloes are raised under an extensive system in the coastal and hilly areas where large-scale pasture land and enough green forage are available. An intensive system for buffalo production is not practiced anywhere in Bangladesh even for institutional herds. The husbandry and care of the animals differs in the two systems. However, there are some common practices such as no housing system, no artificial insemination system, no routine vaccination program and no animal identification and record-keeping system (Saadullah, 2012). One of the most important characteristics of buffalo production in Bangladesh is that they are raised by medium or large farmers who are generally considered rich in the locality. Although buffalo is an integral part of livestock production system in South Asian countries, it has never been addressed in Bangladesh and always neglected despite their important role in the national economy (Hamid et al., 2016). In Bangladesh definite ideal management system of buffalo i.e. about housing, breeding, de-worming, vaccination, animal identification and record-keeping have been improving gradually. Factors like genetic makeup, poor nutritional and management practices, environmental stress, and diseases are the major buffalo health challenges in Asia (Roy et al., 2016). Therefore, considering all the geo-climatic features and the new prospect of buffalo farming, the challenges of buffalo health management and strategic recommendations have been summarized in this review.

Impact of natural hazards on buffalo health

Natural hazards are very common in Asian countries that take place every year and damage crops, livestock and settlements. Buffalo and other animals suffer from fodder crises as a result of natural disasters that has been tripled in the last thirty years (Biswas et al., 2019). Data on livestock, flood, drought, cyclone, tide, thunderstorm, hailstorm, waterlogging, tornado and economic losses were collected and reviewed. Hotspots of natural hazards and damaged area coverage were determined. About 10–32% areas in Asia are prone to moderate and very high natural hazard. Moderate and high drought vulnerabilities were observed about 14% areas for livestock production. Low and very low flood hazards for livestock could be found in 22–44% areas. Hotspots for cyclones covered about 17% areas, high and very high storm/tides about 22% areas and no safe zone against thunderstorm. It is observed that during cyclone buffaloes are often swim away from its main land and sometimes never be traced or found dead, as it is being reared free ranging system resulting huge economic losses. Hailstorm damages are more in south and southeast part of Asia covering about 23.8% areas. Moderate damages by tornado are distributed in 84% areas. Water logging hotspots are in southern parts of Asia covers about 7% areas and livestock about 52% areas suffered from low to moderate water logging problems. As a whole, natural
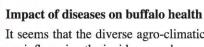
hazards mentioned above are responsible for the economic losses around 1–35 million US$ in livestock (Biswas et al., 2019). Such losses in livestock sector is likely to be increased in future because of the climate change and global warming indicating that proper shelter (locally called Kella) and early warning systems (EWS) would be in place to minimize the damages in buffalo production from natural hazards with special emphasis at the coastal buffalo population (Bathans). Buffalo robbery is another important problem in the remote coastal area of Bangladesh; robbers in the name of fishing steal buffaloes even sometimes beating cowboys take their buffaloes in fishing boat.

Effects of climatic change on buffalo health management

Several livestock health problems are associated with the climate change and global warming system. Heat stress causes increase in parasitic diseases, free radicals concentrations and reactive oxygen that leads to damage of macromolecules and disruption of normal metabolism and physiology. High environmental temperature negatively affect the thermoregulatory mechanism of the testes, sexual desire, ejaculate volume, live sperm percentage, sperm concentration, viability and motility (Lobo et al., 2010). In addition, higher energy deficiencies affect the animal fitness and longevity. High ambient temperature may also affects the endocrine status, metabolic rate, oxidative status, glucose, protein and lipid metabolism, liver function, non-esterified fatty acids (NEFA), saliva production and salivary bicarbonate content (Nardone et al., 2010). In case of buffalo, allowing for wallowing and water sprinkling are successful step for reduction the heat stress mainly during the summer season (Gupta et al., 2016). Calves from cooled cows have higher body weight than calves from stressed cows by heat at birth (42.5 vs. 36.5 kg). Cooled cows have greater milk production (28.9 vs. 33.9 kg/day), lower milk protein concentration (3.01 vs. 2.87%), and tended to have lower somatic cell score (3.35 vs. 2.94) through 280 days in milk than calves from stressed cows by heat (Biswas et al., 2019; Mittal et al., 2019). It is important that such mitigation strategies would focus on the study and use of local genetic resources exhibiting a highly adaptation to the most significant issue for that specific region, either climate or disease. Such markers would be of great importance and use in the definition of selection strategies and improvement of buffalo health and reproductive performance with special preference to the south regions of Asia. Selection practices will be helpful for the genetic improvement of the livestock for important heat tolerance traits. Construction of proper shelter can minimize the heat stress.

Fodder production and its availability and buffalo health

About 200 hectare fodder crop areas are affected each year due to the salinity (Alam et al., 2017) which leads to the fodder shortage and is considered one of the crucial issues for livestock and other animals production. Due to the high dependency on the salinity affected fodder crops, buffalo are suffered by many negative consequences such as diarrhea, skin diseases, liver fluke, loss of body weight, and breakdown of the immune system (Alam et al., 2017). The Coastal agriculture system is predominantly affected by unequal water distribution over the last decades. It has been recorded that there is extreme scarcity of salinity free water (fresh water) in the coastal areas because of the natural disasters such as rising of the sea levels, cyclones, floods and land erosion which brought the saline water from the sea that mixed with the surface and groundwater. Salinity is likely to be increased during dry winter season of every year. Saline water has also a detrimental effect on buffalo health production. Survival of buffalo depends on the field grass, water, feed and fodders. These types of natural resources are connected to saline water. Fodder crisis is more prominent in winter season compare to the other seasons in the coastal region of the country. Tolerance of the saline water varies among classes and species of livestock. Pregnant, lactating, and younger classes of livestock are less tolerant than the mature dry stock (Alam et al., 2017). For optimum production, water supplies should not exceed the optimum salinity levels in the fodder for livestock production. Buffalo grazing on green feed can tolerate better salinity levels at the upper limit of each category compared to those are grazing on dry feed or salt bush and/or on a high salt diet since the high water content of green feed will dilute the salinity levels of the water supply (Upadhyay et al., 2007). Therefore, the salinity levels should be controlled in the coastal regions for buffalo health production.

Impact of diseases on buffalo health

It seems that the diverse agro-climatic conditions, animal husbandry practices and pasture management are influencing the incidence and severity of various diseases on buffaloes health in Asia. But surprisingly, there is no systemic approach has been documented on buffalo diseases and their management. Although buffaloes are being able to survive on marginal land and subsist on low-quality forages, rusticity and greater adaptability to different topographies, soils and climatic factors, they can still be afflicted with various infectious diseases that greatly affect their health. Moreover, the inbreeding system renders the buffaloes prone to various infectious diseases. Buffaloes are more or less susceptible to parasitic infestations, microbial infections, toxic agents, and even dietary deficiencies as observed in other domestic animals like cattle. In general, buffaloes are more resistant to most of the diseases than cattle (Fagiolo et al., 2005).

Diseases of Buffalo calves: Likewise other domestic farm animal, newborn and young buffalo calves are less resistant to diseases than adult buffaloes (Khan et al., 2007). Therefore, calf mortality is one of the major causes of losses in the buffalo farms. Calf pneumonia or diarrhea resulting from management, environmental, nutritional and physiological variations and various microbial and parasitic infectious agents, are the most important causes of buffalo calf mortality. Toxocariasis is one the paramount cause of death among buffalo calves in Bangladesh and known as the number one killer disease of buffalo calves (Dorny et al., 2015; Mia et al., 1975). It is frequently observed that calf is affected with navel ill or joint infection; calves born in unhygienic environment and there is no practice disinfectant at the naval area in association with minimal colostrum intake enhances the disease occurrence (Ahmad, 2019).

Parasitic diseases: Buffalo graze in natural open pasture in coastal areas. Given the ubiquity of parasites in Southeast Asian ecosystems, parasites are more diverse and numerous than their hosts. The prevalence (64.20%) of gastro-intestinal (GIT) parasites is an alarming issue for buffaloes in the buffalo raising zones specially in the coastal regions of the country (Biswas et al., 2021; Biswas et al., 2024). Faecal samples examinations revealed *Paramphistomum cervi* (32.10%), *Fasciola gigantica* (21.60%), *Toxocara vitulorum*(14.56%), *Schistosoma indicum* (1.85%), *Strongyles* (1.85%), *Strongyloides* sp. (1.23% and protozoan species, *Balantidium coli* (38.89%) and *Eimeria* sp. (4.94%) (Biswas et al., 2014; Roy et al., 2016) The parasitic loads were related to the age of the host but sex was not found to affect the incidence. Animals of both sexes were almost equally susceptible to gastrointestinal parasitic infection but younger animals were found to be more prone to GI parasite and protozoa (Islam et al., 2016).   Recently it has reported various species of GI parasites such as liver fluke (24.41%) and amphistomes (78.40%); stomach worms (29.58) and Ascarid worms(18.78%); protozoa, *Balantidium coli* (80.28%) (Biswas et al., 2014; Islam et al., 2016). Therefore, parasitic infestation is a persistent problem in Asia for buffalo health management and increasing the anthelmintic resistance is posing an additional challenge to control parasites.

Microbial diseases: Haemorrhagic septicaemia (HS) caused by the bacterium *Pasteurella multocida*, commonly known as pasteurellosis is the major threat to buffalo health. Buffaloes are more susceptible to HS and die in larger number compared to cattle (De Alwis, 1995). Moist conditions provides the prolong survival of the HS organism and thus the disease tends to spread more rapidly during the monsoon season when rice cultivation also brings about movements of animals. Most of the non-parasitic enteritis caused by *E. coli* (62.5%) and *Salmonella* sp. (29.16%), clinical (23.68%) and subclinical (31.57%) mastitis were reported respectively (Islam et al., 2016). Buffaloes though are comparatively more resistant to many diseases including contagious bovine pleuro-pneumonia, foot root, foot and mouth disease (FMD), anthrax, black quarter and mastitis than cattle (Mondal and Yamage, 2014; Rahman et al., 2017). Incidence of mastitis is high in regions where high yielding buffaloes are kept for milk production. On the other hand, buffaloes are comparatively less resistant to tuberculosis than cattle (Javed et al., 2006). Buffaloes are affected with tuberculosis when they are kept under unsanitary conditions. Sporadic outbreak of cowpox, rabies, tetanus, actinobacillosis and ringworm in buffalo is also reported in many Asian countries, and regional variations are observed in the incidence of these buffalo diseases (Stefferud, 1956). Unfortunately buffalo play a major role in the maintenance and transmission of foot and mouth
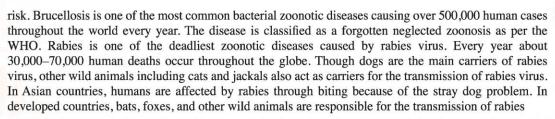
disease (FMD) and remain as permanent carriers (Stefferud, 1956). From an economic point of view, FMD is the most important disease and outbreak in many Asian regions may have detrimental effects on the buffalo industry including the exports of animals, animal products and other agricultural products. A significantly higher number of FMD cases during April–June (pre-monsoon) and November could be due to the increased movement of animals from outside and within the country for trade purposes. The movement of buffalo for management and husbandry purposes is important for local spread of disease.

Emerging infectious diseases of buffalo

Water buffalo is an indispensable livestock in Asia including Bangladesh. It adapts well to tropical climate and has significant contribution to the livestock industry, provided with improved breeding and good animal husbandry practices (Hamid et al., 2016). Infectious diseases are hindrance to good reproductive performance of livestock, resulting in huge economic loss. In addition, most of these diseases are zoonotic, posing serious threats on public health. However, its degree of severity varies in each region and is often overlooked. The common and emerging bacterial, viral, protozoal, fungal and endoparasitic pathogens infect directly, affect the buffalo health condition except for schistosomiasis where water buffalo played an important role as shedder of infection to humans (Villanueva et al., 2018). Leptospirosis, brucellosis, Bovine TB, BVDV and fasciolosis have projected economic impact to buffalo industry as well as its effect as zoonoses. However, the popular buffalo raw milk curd added a potential risk of TB among coastal people (Villanueva et al., 2018). Further studies are needed particularly in coastal regions where water buffalo is the major livestock than cattle to fully utilize the potential of the buffaloes.

Zoonosis and food safety

The "Asia Pacific strategy for emerging diseases: 2010" report estimated that around 60% of the emerging human infections are zoonotic in nature and among these pathogens more than 70% originated from wildlife species (WHO 2010). The newly emerged diseases in humans in recent decades were of animal origin and were directly associated with animal origin foods. More than 60% of human pathogens are zoonotic in origin. This includes a wide variety of bacteria, viruses, fungi, protozoa, parasites, and other pathogens. Factors such as climate change, urbanization, animal migration and trade, travel and tourism, vector biology, anthropogenic factors, and natural factors have greatly influenced the emergence, re-emergence, distribution, and patterns of zoonoses. Zoonotic diseases are caused by a wide range of pathogens. Based on etiology, zoonoses are classified into bacterial zoonoses (such as anthrax, salmonellosis, tuberculosis, Lyme disease, brucellosis, and plague), viral zoonoses (such as rabies, acquired immune deficiency syndrome- AIDS, Ebola, and avian influenza), parasitic zoonoses (such as trichinosis, toxoplasmosis, trematodosis, giardiasis, malaria, and echinococcosis), fungal zoonoses (such as ring worm), rickettsial zoonoses (Q-fever), chlamydial zoonoses (psittacosis), mycoplasma zoonoses (*Mycoplasma pneumoniae* infection), protozoal zoonoses, and diseases caused by acellular non-viral pathogenic agents (such as transmissible spongiform encephalopathies and mad cow disease) . Anthrax can be transmitted to humans through close contact with infected animals (such as cattle and goat) or their products (such as meat, skin, hides, or even bones). Human to human transmission exists, but it is very rare. Every year, about 2,000–20,000 humans are affected by anthrax cases globally. People from India, Bangladesh, Pakistan, Iran, Iraq, South Africa, Turkey are occasionally affected (Goel, 2015). In humans, it can develop malignant pustule, gastroenteritis, pneumonitis; conversely sudden death with some systemic lesions can occur in animals. Mortality can be 25–65% in intestinal anthrax; however, it may rise up to 100% in pulmonary anthrax . Asian countries whose economy usually depends on agriculture are still facing hazardous effects due to anthrax. Among the bovine zoonoses having serious public health significance, tuberculosis is the most important zoonotic disease. The disease has been significantly a cause for severe economic loss in animal production. Most humans are affected with tuberculosis by handling or milking unpasteurized contaminated milk or via aerosols from coughing of infected animals. Importantly, *M. bovis* infection can also happen in the urogenital system of humans and can impact animals through the respiratory secretions from humans acting as reverse zoonoses. However, direct contact of infected animals with humans such as farm workers, veterinarians, abattoir workers, or village people can pose a significant

risk. Brucellosis is one of the most common bacterial zoonotic diseases causing over 500,000 human cases throughout the world every year. The disease is classified as a forgotten neglected zoonosis as per the WHO. Rabies is one of the deadliest zoonotic diseases caused by rabies virus. Every year about 30,000–70,000 human deaths occur throughout the globe. Though dogs are the main carriers of rabies virus, other wild animals including cats and jackals also act as carriers for the transmission of rabies virus. In Asian countries, humans are affected by rabies through biting because of the stray dog problem. In developed countries, bats, foxes, and other wild animals are responsible for the transmission of rabies

Zoonosis involves the interaction of humans, animals, and environment, and therefore a multi-sectorial approach is required to ensure effective control measures (Chomel, 2008). Other activities for the control of zoonoses include issuing laws and regulations related to the isolation and quarantine, establishment strong and effective disease reporting (notification) systems, farm biosecurity, mass vaccination, test and slaughter or cull, public awareness, and health education. Mass media and electronic information system, social networks, text messages and other communication channels can play a significant role in increasing public awareness to control zoonoses.

Surveillance is crucial to prevent and control zoonotic diseases. It can be used to detect early infection, affected humans and animals, reservoirs, vectors, and endemic areas including the "hotspots". It helps in the adaptation of control strategies against emerging and re-emerging diseases to improve human health status, to manage disease properly, and to minimize morbidity and mortality of humans and animals. Since zoonoses (such as SARS and HPAI) can spread swiftly across the globe to affect global communities, coordinated surveillance approaches at local, regional, national, and international levels are essential to control zoonoses. Successful and functional surveillance requires well equipped lab, adequate diagnostic facilities, skilled manpower and funding. All disease control measures require a substantial amount of financial support that is usually unavailable for most of the Asian countries. The developed countries and international donors need to support the developing countries for effective zoonoses control. Donor agencies such as WHO, Food and Agriculture Organization of the United Nations (FAO), World Organization for Animal Health (OIE), US Agency for International Development (USAID), US Department of Agriculture (USDA), European Union (EU), Department for International Development (DFID), Biotechnology and Biological Sciences Research Council (BBSRC), and Danish International Development Agency (DANIDA) could be approached for funding. Similarly, private funding bodies like the Welcome Trust and the Bill and Melinda Gates Foundation can also be approached for funding to implement zoonoses control programs.

In order to control food-borne zoonoses, an ample supply of safe food has to be made available for consumers. This could be achieved through implementing two broad approaches: risk assessment and risk management of food products. Risk assessment can be conducted through collecting and analyzing data, and by providing recommendations based on importance; risk management should be adopted by taking legislative measures and setting targets to reduce the risk. Animal-origin foods such as meat, milk, and eggs have to originate from healthy animals that are free of zoonotic pathogens. Proper ante-mortem and post-mortem examination of animals is vital to ensure safety of food from animal origin. Ensuring hygienic conditions in every step of food processing including personal hygiene of personnel involved in food processing need to be monitored for the production of safe food.

Lack of preventive measures and inadequate immunization

Development of a protective level of immunity against any disease requires effective vaccines. There is a routine FMD, HS and anthrax vaccination program for livestock as well as in buffalo at coastal regions. It has been reported that 70% farmers in coastal areas vaccinated their buffalo, where 66 % vaccination was done for FMD, 24 % for Black quarter (BQ) and 20% for HS, respectively (Islam et al., 2016). However, the vaccination coverage was found to be very low. As part of vaccination campaigns, the authority should assess vaccine efficacy, develop a strategy to improve the coverage and conduct sero-surveillance to determine the coverage and the duration of immunity. The present government program on modernization of livestock vaccine production is expected to increase quality of vaccines production, and the vaccination program should be implemented in disease endemic areas which will alter the disease epidemiology.

Limited veterinary services

The limited manpower and lack of transport restricts the ability of the veterinary surgeons to respond to all reported cases. Each upazila / subdistrict has only one veterinary surgeon to look after all the livestock in the area and one livestock officer for the administrative tasks. These problems are more evident in the remote coastal regions. Recently, Bangladesh government has taken a initiative to increase the veterinary services by recruiting Livestock Extension Officer (LEO) and also transportation facilities through DLS projects.

Indiscriminate use of drugs – Antimicrobial and Anthelmintic Resistance
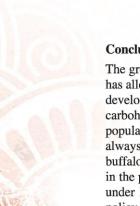
Application of veterinary drugs in livestock is inevitable as they are essential for the treatment of diseases, prevention and control, modification of physiological functions, improvement of growth and productivity as well as for ensuring the food safety. However, recent reports have revealed that indiscriminate use of veterinary drugs results in deposition of antimicrobial residues in muscle and organs of animals (Falowo and Akimoladun, 2019). The role of poor quality veterinary medicines is a driver of antimicrobial resistance. Studies have been found that residues of antibiotics and medicines used to treat infections caused by bacteria, protozoa, helminths and fungi accumulate in buffalo meat and milk (Basantia and Saxena, 2012). Organisms with multi-drug resistance are resistant to three or more different classes or types of drugs used to treat them. Very often, this is what it means to be a 'superbug'. Superbugs are often very difficult and very time consuming to treat The increasing development of anthelmintic resistance (AR) in parasites of livestock is threatening animal health and production worldwide (Sutherland and Leathwick, 2011; Biswas et al., 2022; Hasan et al., 2022; Parvin et al., 2022). It is urgent to determine the extent of liver fluke and other parasitic resistance to explore current research gaps of the situation of AR (Coles, 2003). Amid lax monitoring by the authorities and a lack of veterinary officers at upazila and union levels, rural farmers opt for antibiotics because of their easy accessibility and availability in pharmacies and ability to yield quick results. Farmers in many areas rely on quacks and compounders amid a shortage of trained veterinarians.

Disease surveillance of buffalo population and information communication gaps

Disease surveillance: Regular disease surveys of buffalo populations are also important for buffalo health. This review indicates the widespread distribution of a number of diseases in Asia. The underlying factors could result from differences in the animal husbandry practices in different geographic locations, culture habits of animal uses, agro-climatic factors, lack of regulation of animal movements, lack of adequate vaccination and lack of knowledge about the epidemiology of the diseases. In order to obtain a functional disease-status data base of each buffalo farm, the local veterinarian must be informed timely of any buffalo hunting, culling, or "hands on" manipulation, where the animals may be sampled for disease screening purposes. The disease surveillance should be improved throughout the coastal regions.

Buffalo Disease testing Laboratory: All buffalo must be tested for all relevant diseases prior to movement off the farm. Furthermore, disease testing of a buffalo herd or a percentage may be ordered by the Upazila livestock office (ULO) at any time, if circumstances demand this action. The need for establishing modern diagnostic laboratory for the confirmation of clinical cases in the regions is imperative. Probably, the most significant would be the identification and monitoring the circulation of the pathogens in the free-range and household buffalo populations. The findings from the tests will constitute baseline data and provide the prompt for investigation to better understand the epidemiology of important buffalo diseases.

ICT-based program for better health and services: Introduction of web-based software, viz Livestock Disease Information System (LDIS), recently developed with the support from FAO ECTAD for reporting livestock diseases in Bangladesh that will enable tracking field cases of all diseases on a daily basis. The LDIS program should be implemented in other Asian regions. Since the use of the cell phone-Web based SMS-(Short Message Service), Gateway system has been successful with the surveillance of HPAI H5N1 in Bangladesh and is popular nationally and internationally, this can also be of value for the surveillance of other important animal diseases and any other buffalo health issues at the remote regions.

Conclusion

The growth of human population in Asia has been accompanied by unprecedented economic growth that has allowed increases in income and purchasing capability and changes in food preferences. These recent developments have major impacts on the demand for animal derived products, meat and milk rather than carbohydrates. Therefore, a major challenge for the future is to sustain the need for food of a fast-growing population in the country. The contribution of buffaloes to the livestock industry of Asian countries has always been measured by the value of milk, meat, hide and leather. Disease risk management directive for buffalo health and strategic plans to overcome the buffalo health issues in this region have been indicated in the particular section of this review. Establishment of a buffalo regional research centers is necessary under Buffalo Advisory Committee (BAC) with academician, experienced veterinarians and livestock policy makers to advise and assist regional governments to solve buffalo related issues and improve buffalo production in buffalo raising areas of Asia. Buffalo health management in Asia is very challenging because it must address related all issues in socioeconomic and natural approaches on various aspects of ecosystems, resources, natural hazards, climate change, diseases and their impacts, effective response by the concerned authority. The most important is to have interlinked among the government and non-government authorities with local buffalo farmers in any approaches that could ensure buffalo health and sustainability of buffalo farming in Asia.

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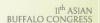
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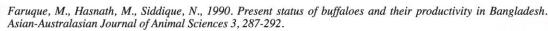
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ORAL PRESENTATION

Comparative bacteriome diversity andcomposition across buffalo milk chain in Bangladesh: insights into mammary health and microbial contamination

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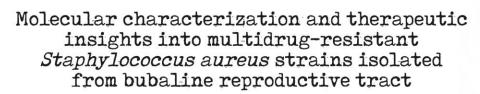
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Abstract

This study examined bacteriome diversity and composition across stages of the buffalo milk supply chain in Bangladesh: healthy milk (HM), subclinical mastitis (SCM), and bulk milk (BM). Fifteen farms provided samples meeting criteria for both CMT-negative, culture-negative HM and CMT-positive, culture-positive SCM. A total of 45 milk samples (HM = 15, SCM = 15, BM = 15) underwent DNA extraction using the Maxwell® 16 Cell DNA Purification Kit, targeting the V3 – V4 regions of the 16S rRNA gene, followed by sequencing on the Illumina MiSeq platform. Alpha-diversity analysis revealed significant differences (P = 0.005) between BM and SCM milk compared to HM. However, beta-diversity (PERMANOVA: R2 = 0.197, P = 0.069) did not show distinct clusters among the sample groups. SCM samples consistently exhibited higher bacteriome composition and abundance compared to BM and HM. In total, 251 bacterial genera were identified, with 152 genera (~60%) common across HM, SCM, and BM. Staphylococcus dominated SCM (64.1%) and HM (41.1%) samples, whereas it was lower in BM (14.4%). SCM also featured Cellulomonas (6.5%), Macrococcus (5.8%), Acinetobacter (4.2%), and Pseudomonas (2.4%). HM samples showed Macrococcus (15.5%), Cellulomonas (10.6%), and Cutibacterium (4.4%) as primary genera, while BM was dominated by Staphylococcus (14.4%), Macrococcus (14.1%), Chryseobacterium (10.9%), Lactococcus (10.5%), and Acinetobacter (9.7%). Among 491 bacterial species detected, SCM, BM, and HM showed exclusive associations with 33, 61, and 15 species, respectively, while 199 species (40.5%) were shared. Staphylococcus aureus was most abundant in SCM (55.4%) and HM (43.9%), with lower abundance in BM (14.5%). Macrococcus lamae predominated in HM (20.2%), while Streptococcus suis was highest in BM (23.0%). These results highlight distinct bacterial profiles in different milk types, aiding in pathogen differentiation between HM and SCM, indicating mammary dysbiosis and potential bacterial contamination in water buffalo BM.

Keywords: Subclinical mastitis milk, healthy milk, bulk milk, 16S rRNA gene sequencing, bacteriome diversity.

Molecular characterization and therapeutic insights into multidrug-resistant *Staphylococcus aureus* strains isolated from bubaline reproductive tract

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Abstract

Multidrug-resistant bacteria have become the predominant etiology in bovine female reproductive tract infections and thus require effective treatment approaches. The main goal of this study was the molecular detection of mecA, blaZ, tetK, and aacA-aphD genes in *Staphylococcus aureus* (*S. aureus*) responsible for methicillin, beta-lactam, tetracycline, and aminoglycoside resistance respectively. Phylogenetic analysis was conducted to check the homology of staphylococcal genes with NCBI sequences. The in-vitro efficacy of non-steroidal anti-inflammatory drugs (NSAIDs) in combination therapies against MDR *S. aureus* was evaluated using well diffusion assay and checkerboard method. Vaginal swab samples (n = 384) collected from bovines suffering from endometritis, pyometra, and retained placenta were tested for *S. aureus*. Results showed a 17.96% overall prevalence. Both phenotypic and genotypic resistance was observed among *S. aureus* isolates with 50.72% and 37.68% isolates being confirmed as methicillin-resistant (MRSA), 36.23% and 18.84% isolates exhibiting beta-lactam, 40.58%, and 27.54% isolates showing tetracycline, and 33.33% and 36.23% isolates showing aminoglycosides resistance based on disc diffusion and gene confirmation, respectively. Phylogenetic analysis indicated homology with previously reported Pakistani isolates suggesting the possibility of MDR *S. aureus* transmission within and between animals. Synergy testing indicated that combinations of ceftriaxone-ketoprofen (153.77%), ceftriaxone-meloxicam (149.55%), amoxiclav-flunixin meglumine (106.06%), and oxytetracycline-flunixin meglumine (104.47%) showed synergy on well diffusion assay. Based on the fractional inhibitory concentration index by checkerboard method, oxytetracycline-meloxicam and gentamicin-ketoprofen combinations exhibited synergistic interaction. In conclusion, MDR *S. aureus* resistance was mitigated in-vitro through the combination of antibiotics (oxytetracycline, gentamicin) with NSAIDs (meloxicam, ketoprofen) that could be used to create therapeutic strategies for bovine reproductive issues.

Keywords: Antibiotic resistance, genetic characterization, TRSA, ARSA.

Shotgun metagenomics for the identification of diarrheal pathogens in gut microbiota of buffalo calves in Bangladesh

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Abstract

The prevalence of gut protozoa is often underestimated due to the lack of adequate detection and surveillance systems. Metagenomics provides an opportunity, allowing simultaneous detection of multiple symbionts in a single analytical procedure. This study aimed to accurate estimates of their

POSTER PRESENTATION

prevalence and to better understand the role and ecological dynamics of gut microbiota of buffalo calves using shotgun metagenomics. A number of diarrheic fecal samples were collected from buffalo calves of which four of them had bloody diarrhea, four affected with watery diarrhea and seven were healthy calves. The microbial flora of these samples was analyzed by shotgun metagenomics. Protozoal parasites were detected in the metagenome sequences and identified using PCR.Cryptosporidium, Eimeria, Giardia, Blastocystis and Entamoeba were detected by metagenomic analysis and the identified species were Giardia duodenalis assemblage E, Cryptosporidium bovis, Eimeria bovis, Eimeria subspherica, Entamoeba bovis, and Blastocystis ST2 and ST10. Metagenomic analysis showed that the intestinal microbes of calves with diarrhea were disordered, especially in calves with bloody diarrhea. Furthermore, different parasites showed distinct relationships with intestinal microecology. Cryptosporidium, Eimeria, and Giardia were negatively correlated with various intestinal bacteria but positively correlated with some fungi. Twenty-seven biomarkers were not only significantly enriched in bloody diarrhea, watery diarrhea, and healthy calves but were also associated with Eimeria, Cryptosporidium and Giardia. Only Eimeria showed a distinct relationship with seven genera of bacteria, which were significantly enriched in the healthy calves. All 18 genera of fungi were positively correlated with Cryptosporidium, Eimeria, and Giardia, which were also significantly enriched in calves with bloody diarrhea. This study revealed the relationship between intestinal protozoan parasites and the other gut microbiota in buffalo calves. Different intestinal protozoan parasites have diametrically opposite effects on other gut microecology, which not only affects bacteria in the gut, but also is significantly related to fungi and archaea.

Keywords: Buffalo calves, gut microbiota, parasites, metagenomics.

Genetic variability of *Toxocara vitulorum* in buffaloes of Bangladesh

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Abstract
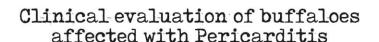
Toxocara vitulorum is one of the deadliest parasite of buffalo calves in Bangladesh. This study was conducted to explore genetic variability within and among the *T. vitulorum* populations in buffalo calves of Bangladesh. Genomic DNA was extracted, *ITS2, COX1* and *NAD1* gene were amplified and sequenced. vDistinct 29 *ITS2*, 21 unique *NAD1* and 24 *COX1* genotypes were detected among the *T. vitulorum* of different geographic regions. These three gene genotypes identities ranged from 97% to 99%, when compared with each other/best hit scoring *T. vitulorum* sequences retrieved from GenBank. A total of 12 and 6 unique haplotypes were detected for *COX1* and *NAD1* gene sequences. The average nucleotide and haplotype diversity for *COX1* and *NAD1* were 0.01691 & 0.89493 and 0.00658 & 0.77895 respectively and the recorded values were more dispersed than previously published values. For *COX1* and *NAD1* gene, Fst and Nst ranged from 0.0002 to 0.9484 and 0.000 to 0.9473, respectively whereas for *NAD1* Fst and Nst ranged from 0.0002 to 0.9211 for both cases reportedly higher than other published reports. The study findings will be helpful for further extensive epidemiological studies regarding anthelmintic resistance, control and prevention of *T. vitulorum* infection in buffalo calves.

Keywords: TBuffalo calves, genetic variability, phylogeny.

Clinical evaluation of buffaloes affected with Pericarditis

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Abstract

This study was designed to evaluate the buffaloes presented with brisket edema to Large Animal Clinic, Teaching Veterinary Clinical Complex, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana. A total 78 buffaloes presented with primary complaint or history of brisket edema were included in the study. All the animals were subjected to physical examination, radiography, thoracic and abdominal ultrasonography. Out of these, 55 buffaloes were confirmed for pericarditis on ultrasonography. Physical examination revealed ventral edema along with brisket edema in eight buffaloes. Bilateral jugular engorgement was observed in 41 animals. The CVS examination revealed normal intensity of heart sounds in 20, muffling in 35 and fluid sounds in nine buffaloes. Pericarditis was confirmed to be associated with reticular foreign body upon abdominal radiography in 17 buffaloes. On ultrasonography heart was visibly compressed in 38 cases due to the excessive pericardial fluid. Buffaloes in the study had only pericardial effusions in 23, both pleural and pericardial effusions in 25 and simultaneous pleural, pericardial and peritoneal effusions in seven buffaloes. It is concluded that ultrasonography and echocardiography is mandatory for definitive diagnosis of such cases as edema can be presented in other affections as well.

Keywords: Edema, pericarditis, ultrasonography.

Pneumonia in buffalo calves and its therapeutic management in buffalo farms

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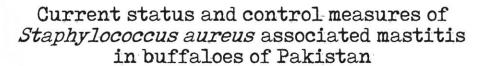
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Abstract

Although buffaloes play very important role in rural economy of Bangladesh, researches on buffalo diseases are surprisingly scarce in the country. Therefore, the study was undertaken to investigate buffalo calves pneumonia in selected buffalo farms in Bangladesh in order to help develop appropriate control and preventive measures. Both retrospective and prospective investigations on the incidence and prevalence of buffalo calves pneumonia were conducted for a period of one year. Laboratory analyses were conducted on biological samples (nasal swab, feces) to identify the causal agents for buffalo calves pneumonia recorded having nasal-oral-ocular-discharge, coughing, sneezing, labored breathing, depression, lethargic, diarrhea among Tharparkar and Murrah buffalo calves from 0-3 months of age. During the study of 100 calves, 58.46% were found to have diarrhoea, pneumonia or its combination. However, 41.54% were showed only respiratory sign. Parasitic pneumonia were 11.24% and 12 calves were died, constituting 9.09% of the total calf mortality born during the study period. Diseased calves were treated with piperazine, levamisole hydrochloride, piperazine and levamisole hydrochloride combination. Piperazine and levamisole combination showed better result and others are treated with antibiotic like streptomycin, tetracycline and sulfhonamides. Around 88% of treated calves were recovered. The study unveiled a comprehensive scenario of buffalo calves pneumonia in Bangladesh in relation to casual agents and predisposing factors.

Keywords: Buffalo calf, pneumonia, prevalence, treatment, management.

POSTER PRESENTATION

Current status and control measures of *Staphylococcus aureus* associated mastitis in buffaloes of Pakistan

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Abstract

Antimicrobial resistance (AMR) becomes a challenging issue that limits the therapeutic options for both veterinary and public health professionals. Among various diseases in buffaloes, mastitis significantly reduces milk yield and quality, leading to substantial economic losses in dairy farming around the globe. The current study was designed to characterize methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Staphylococcus aureus* (VRSA) isolated from subclinical mastitis in buffaloes, along with its response to antibiotics, and ultimately reverse its mechanism of resistance by modulation with non-antibiotics. The overall prevalence of subclinical mastitis and *S. aureus* was recorded to be 61.98% and 28.90% respectively. Out of total *S. aureus* isolates, 19.82% were declared as MRSA while 09.01% were confirmed as VRSA on genotypic basis. The BLAST alignment of current study sequences revealed 99% similarity with mecA and vanB genes of MRSA and VRSA from NCBI database and other reference gene sequences from Turkey, India, and Russia. Antibiogram profiling of MRSA and VRSA positive isolates showed a highly resistant response to cefoxitin, amoxicillin, and gentamicin. Amoxicillin, gentamicin, tylosin, vancomycin, and ciprofloxacin elicited a significant response ($p < 0.05$) in combination with non-antibiotics against tested MRSA isolates. The highest zone of inhibition (ZOI) increase was noted for vancomycin in combination with flunixin meglumine (145.45%) and meloxicam (139.36%); gentamicin with flunixin meglumine (85.71%) and ciprofloxacin with ivermectin (71.13%). Synergistic behavior was observed in the combination of gentamicin with ketoprofen; sulfamethoxazole and oxytetracycline with meloxicam. The highest cure rate was observed in case of gentamicin in combination with ketoprofen as compared to other treatment groups. The current study concluded antibiotics in combination with non-antibiotics as potential therapeutic agents for resistance modulation against different antibiotic resistance strains of *S. aureus*. This study will help to devise treatment and control strategies against bovine mastitis.

Keywords: AMR, subclinical mastitis, MRSA, antibiogram.

The case report of mite infestation in buffalo calves and their therapeutic effects in coastal region of Bangladesh

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Abstract

This case report documents an outbreak of mite infestation in buffalo calves, specifically caused by Sarcoptes scabiei var. bovis, in Velumia Bathan area of Bhola district, a coastal region of Bangladesh. About 25 affected buffalo calves, aged 3-6 months, were presented with severe pruritus, skin eruption, alopecia, thickened and crusted skin lesions, restlessness and weight loss. Diagnosis was confirmed through deep skin scrapings and microscopic examination, which revealed the presence of mites. Treatment involved topical and systemic administration of ivermectin along with supportive care and environmental management. After

3 days of these treatments, topical 20% methylene blue (MB) was sprayed and significant improvement was observed within two weeks, with complete resolution of symptoms and no recurrence after three months. This case underscores the importance of early diagnosis and effective treatment of mite infestations in buffalo calves, highlighting the need for vigilant calf's management practices to prevent outbreaks and ensure animal welfare to protect the health of buffalo calf population. Veterinary practitioners should consider mite infestations in the differential diagnosis of pruritic skin conditions in livestock and implement appropriate therapeutic and management strategies.

Keywords: Buffalo calf, mite, sarcoptes scabiei, ivermectin, methylene blue.

Prevalence and diversity of ectoparasites in buffalo in selected districts of Bangladesh

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Abstract
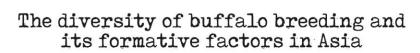
Infestations of ticks and lice ectoparasites in buffaloes have a potential impact of health as these ectoparasites suck blood and act as vector of protozoan diseases. Ectoparasite-related illnesses are serious because they reduce health, growth, work output, milk and meat production. Ticks and lice are extremely dangerous to buffaloes because they spread diseases and there are several vector-borne illnesses and zoonotic diseases. The objective of this study was to determine the prevalence and diversity of ectoparasites among buffalo population in selected regions of Bangladesh. A total of 311 buffaloes were randomly examined for ectoparasites and among these, 172 buffaloes were infested a number of ectoparasites. This study revealed an overall 55.30% prevalence of ectoparasites. However, ectoparasitic prevalence in Mymensingh (55.14%), Bhola (54.73%) and Sandwip (55.96%) were determined. The prevalence of ectoparasites is higher in females (Mymensingh 67.56%, Bhola 58.57% and Sandwip 58.44%) compared to males (Mymensingh 48.85%, Bhola 44% and Sandwip 50%). The prevalence of tick infestation was relatively higher in buffalo calves (Mymensingh 75%, Bhola 75% and Sandwip 80%) aged 0.5–2 years followed by young (Mymensingh 63.15%, Bhola 64.70% and Sandwip 35.50%) aged >2–5 years and lowest in older (Mymensingh 51.25%, Bhola 35.50% and Sandwip 51.25%) aged >5 years. It is concluded that ectoparasites are a major threat to the buffalo population in the study areas. Therefore, attention should be given to control this tick and lice to minimize the production loss in buffalo farms.

Keywords: Buffalo, ectoparasitic diversity, ticks, lice, prevalence.

11th ASIAN
BUFFALO CONGRESS

POSTER PRESENTATION

SCIENTIFIC SESSION

MANAGEMENT ECONOMY AND SOCIOLOGY

The diversity of buffalo breeding and its formative factors in Asia

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Abstract

The water buffalo, which was probably domesticated in India about 5,000 years ago, has since been used mainly in Asia for agriculture, transportation, and meat and milk. Three different methods of buffalo rearing have been introduced in Asia. The first is the buffalo barn-keeping method. In South Asia and Japan, buffaloes have been reared in sheds with a few buffaloes and fed to produce milk for cash. The next is buffalo grazing. This form of grazing is widespread from Southeast Asia (Lombok Island, Indonesia) to South Asia (Assam, India). In this case, herders may or may not be present in herds of several dozen or more than a hundred head. Finally, there is migratory herding. In the coastal areas of Bangladesh and the mountain area of the Himalayas, camps have been established for buffalo rearing, and a form of seasonal migration of herders and buffalo herds is known like the case of the Gujjars people. This study aims to understand where in Asia the diversity of buffalo rearing is found in India, and to examine the factors that give rise to such diversity. We will also consider the significance of the practice of crossbreeding between buffalo and wild buffalo during buffalo grazing.

Keywords: Breeding, barn-keeping. grazing, migratory herding, crossbreeding, Asia.

Pastoralism in the management of indigenous dairy buffaloes of Bangladesh

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Y. Takashahi[3], K. Nomura[3], k. Ikeya[4] and T. Amano[3]

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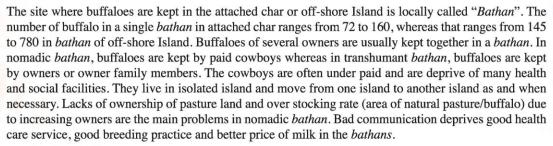
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Abstract

Water buffalo is one of the important animal genetic resources in Bangladesh. The utility of water buffaloes of Bangladesh has shifted nowadays from draught to dairy purpose due to socio-economic trend. Dairy buffaloes of the country, once neglected, are now honoured due to their outstanding food value and quality of milk and meat. Dairy buffaloes of Bangladesh are mostly indigenous type and their milk production is low. Almost 95% of dairy buffaloes of the country are reared under either nomadic system or transhumant system. They are reared mainly in the attached chars of Padma, Brahmaputra river basin under transhumant pastoralism and in the off-shore islands of Bay of Bengal under nomadic pastoralism.

The site where buffaloes are kept in the attached char or off-shore Island is locally called "*Bathan*". The number of buffalo in a single *bathan* in attached char ranges from 72 to 160, whereas that ranges from 145 to 780 in *bathan* of off-shore Island. Buffaloes of several owners are usually kept together in a *bathan*. In nomadic *bathan*, buffaloes are kept by paid cowboys whereas in transhumant *bathan*, buffaloes are kept by owners or owner family members. The cowboys are often under paid and are deprive of many health and social facilities. They live in isolated island and move from one island to another island as and when necessary. Lacks of ownership of pasture land and over stocking rate (area of natural pasture/buffalo) due to increasing owners are the main problems in nomadic *bathan*. Bad communication deprives good health care service, good breeding practice and better price of milk in the *bathans*.

Keywords: Dairy buffalo, management, pastoralism.

New technologies and digitalization in buffalo farming

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Abstract

In recent years, the introduction and development of sensors for continuous monitoring of individual parameters have deeply impacted the livestock sector, particularly in poultry, pig and dairy cattle farming. Buffalo farming, instead, lacks solid experimental evide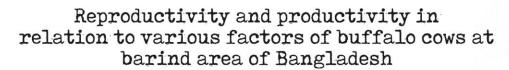nce of their real usefulness and efficiency. For this reason, the project "Digital technologies in the buffalo milk supply chain" aimed to investigate how these technologies could help in buffalo farming technical management and reduce its environmental impact by developing multivariate and buffalo-specific indices. Activometers made it possible to characterize a daily activity highlighting a strong effect of climatic conditions. Significant variations in behaviour were detected both for physiological states (lactation vs. dry $p<0.0001$) and for seasons (winter vs. summer $p<0.0001$). The laser methane detectors (LMD) allowed the study of the distribution and the main environmental factors influencing methane emission as days in milk ($p<0.0001$) or parity ($p<0.0001$). The weight and body condition prediction models through video image analysis (VIA), obtained without compromising the herd routine, demonstrated high accuracy with correlations of 0.93 and 0.95, respectively. The microbiota analysis on different matrices (rumen content, feces, and buccal swab), and the direct measurement of enteric methane using LMD, showed a strong and negative correlation between bacteria and methane emission ($r= 0.88$ for rumen bacteria; $r= 0.81$ for fecal bacteria). Thermal stress assessed through repeated measurements of reactive oxygen species (ROS), biological antioxidant potential (BAP) and oxidative stress index (OSi), showed that the levels of ROMs, BAP and OSi were affected by season ($p<0.01$, $p<0.03$ and $p<0.0001$, respectively). A sensor-based approach in buffalo farming has the potential to facilitate the optimization of the management strategies according to the specific needs of individual animals, and the development of buffalo-specific health and welfare indices.

Keywords: Smart farming, laser methane detectors, enteric methane, animal health and welfare, thermal-stress parameters.

ORAL PRESENTATION

Reproductivity and productivity in relation to various factors of buffalo cows at barind area of Bangladesh

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Abstract

The present study was to evaluate the reproductivity (age at puberty, gestation length, birth weight, age of first calving, post-partum heat period and calving interval), productivity (lactation length, daily milk yield and birth weight of calf) and management system (general management, housing, feeding, calf rearing and treatment facilities) of indigenous buffalo cows using pre-tested questionnaire during the period from January to June 2022. The study was carried out by the Department of Veterinary and Animal Sciences, Faculty of Veterinary and Animal Sciences, Rajshahi University, Rajshahi, Bangladesh. Buffaloes were reared at Barind area. These farm is located in Km 20-30 Poba and Godagari Upazila under Rajshahi district. A total of 200 buffalo cows were randomly selected and interviewed to collect data on reproductive and productive performances in relation to managemental factors of buffalo cows by using pre-tested questionnaire. The average mean ± SD value of reproductive and productive performances were as age at puberty (AP), age at first calving (AFC), gestation length (GL), post-partum heat period (PPHP), calving interval (CI), milk yield per day (MYPD), lactation length (LL) and birth weight of calf (BWC) were recorded as 35.05±4.00 months, 46.26±4.24 months, 308.28±12.46 days, 103.20±28.30 days, 420.36±15.41 days, 3.71±0.57 litre, 206.76±30.54 days and 28.24±4.05 kg, respectively. The middle age (4 to < 7yrs), >350 kg body weight and very good body condition had shown better reproductive and productive performances than others groups. The good quality feed, regular deworming and preventive measures as well treatment taken from DLS, allopathy drugs and medium size farm were observed a good reproductive and productive performance than other groups, respectively. It could be concluded that the buffalo owners of these areas do not follow any scientific method of buffalo husbandry; they just follow traditional rearing system but the farmers mostly used indigenous buffalo cows for dairy purpose for long time at barind area specially Padma char of Rajshahi in Bangladesh.

Keywords: Buffalo cows, reproductivity, productivity, performance, management and Barind area.

Agro-pastoral animal husbandry of buffalo: from settled rearing to transhumance in case of Nepalese mountain villages

Kazuyuki Watanabe
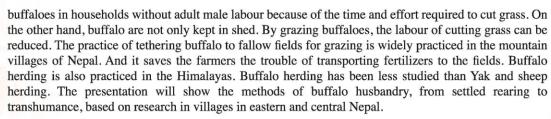
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Abstract

In the Himalayan region, buffaloes have been kept as rural livestock alongside cattle. In recent years, improved breeds of buffalo have been introduced as a white revolution and are known to sell milk. But this requires investment in concentrate feed as well as green fodder. In addition, buffaloes require more fodder than cattle. In Nepalese villages where overseas migration is widespread, cattle are preferred over

ORAL PRESENTATION

buffaloes in households without adult male labour because of the time and effort required to cut grass. On the other hand, buffalo are not only kept in shed. By grazing buffaloes, the labour of cutting grass can be reduced. The practice of tethering buffalo to fallow fields for grazing is widely practiced in the mountain villages of Nepal. And it saves the farmers the trouble of transporting fertilizers to the fields. Buffalo herding is also practiced in the Himalayas. Buffalo herding has been less studied than Yak and sheep herding. The presentation will show the methods of buffalo husbandry, from settled rearing to transhumance, based on research in villages in eastern and central Nepal.

Keywords: Fodder, labor, mobility, altitude.

Buffalo production improvement attributes in reducing poverty at Bhola coastal area in Bangladesh

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Abstract

The study aimed to gather data on home agricultural techniques for buffalo husbandry, farmers' status, issues they encountered, and potential remedies. Data were collected from one hundred twenty (120) randomly interviewed household farmers of two coastal upazilas (Charfesson and Monpura) of Bhola districts in Bangladesh through questionnaire from 2 October, 2023 to 30 June, 2024. Collected data were analyzed by SPSS software. The results showed that Buffalo rearing was practiced by male farmers (85%) having primary level education (51.25%) and belonged to small category of farmers (52.5%) whose main occupation was agriculture (76.25%). About 82.5% farmers used own capital while 96.25% farmers practiced buffalo rearing without any training. Majority (80%) of the farmers had small herd size (<6) where highest number (91.25%) of farmers kept female buffaloes. About 77.5% of farmers did not care for housing of their buffaloes. Among the sheds provided mainly at night (85%), most of them had tinned roof (91.25%), muddy floor (97.5%), inadequate floor space (70%) and improper drainage system (65%). Maximum farmers (90%) practiced grazing their buffaloes from morning to evening at public land & bathan. Clean drinking water supply (3.75%) was very poor practice although farmers had opportunity. Natural breeding (85%) was more prominent practice and buffaloes mainly showed heat in winter. About 45% and 60% farmers practiced irregular vaccination and de-worming respectively. There was no dairy buffalo ration, $PGF2\alpha$ method of estrous synchronization and no buffalo manure management composting practices in the study area. The overall observations indicated that scientific management practices to exploit inherent capacity of buffaloes were not adopted by farmers and hence, management practices were not satisfactory and need to be corrected measured through motivation of murrah breed, training, action research and providing extension services among farmers to improve their present socio-economic condition. Therefore, the findings of the study might be help for poverty reduction as well as improved attributes of Buffalo (*Bubalus bubalis*) production techniques.

Keywords: Buffalo husbandry, attributes, poverty reduction, Bhola coastal area.
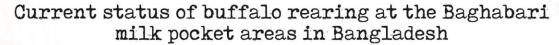
ORAL PRESENTATION

Buffalo farming in Canada-An overview

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Abstract

Buffalo has been in Canada since the early 2000's. First animals were on Vancouver Island in British Columbia. In the later 2000's more farms appeared in Ontario and Quebec. Some farms process their own milk and others have contracts with cheese processors. As of 2024 in Ontario, there are some Amish and Mennonite farms with a co-operative, a few farms raising buffalo for meat production, some of which buy in buffalo dairy products for their customers, and some farms doing a mixture of meat and milk on farm. Most provinces across Canada now have a herd of buffalo for either meat or milk production. At Koskamp Family Farms Ltd, we had our first young animals from this herd arrived in October 2007 from Florida, USA. Over the next year 2 more groups of young animals arrived to start a herd of approximately 120 animals. Breeding with bulls and some artificial insemination our first animals started to milk in 2009. All milk was contracted to Quality Cheese (an Italian cheese company run by the Borgo family). With the milk production also began new challenges, what to do with bull calves. Over time a meat market was created, marketing steers as an alternative for red meat (Tenderbuff). Steers are sent for harvest at approximately 362.87 - 408.23 kg, reaching this weight around a year of age on a corn-based finishing diet. The meat having lower cholesterol is a good selling point. Koskamp Family Farms (KFF) at this time was operated by Fred and Irene Koskamp also but is currently operated by Henry and Inge Koskamp and their 5 children after a successful transition plan. At KFF we milk 120 Holstein cows, 220 buffalo, crop @800 acres of land to feed animals, operate a 600KW biogas facility, and broiler chicken operation. The operation also works with local farmers and grows cover crops which are harvested as forage for the livestock herds. Cattle are milked in a 33-stall rotary parlour built in 2016 using pedometers for electronic identification, activity and transition cow health (rumination, eating time and inactivity). In 2023 a new facility was built with 634 stalls for cattle which has access to the parlour from 2016. Now all animals are identified with neck band which record a variety of parameters. In the past 8 years, all breeding is done with Artificial Insemination with semen purchased and imported from Italy. Looking at dam production and components, we choose sires for future breeding. Able to achieve a pregnancy rate of 25% on the mature herd. All heifers are first serviced with sexed semen. In 2021, Henry and Inge's children purchased another 25 mature buffalo and began Kampkreek Dairies. Kampkreek Dairies started with selling fluid milk and other dairy products. They have since acquired the meat brand (Tenderbuff) from Koskamp Family Farms Ltd. supplying Asian grocery stores in Toronto as well as some other cities, also providing a variety of home distribution routes in South-Western Ontario. Not all stores listed on the website sell all products but choose which products they wish to carry.

Keywords: Canada, Buffalo, Farming.

ORAL PRESENTATION

Current status of buffalo rearing at the Baghabari milk pocket areas in Bangladesh

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Abstract

Buffalo is the most neglected species of large ruminant, despite contributing to safe and sustainable milk and meat production in Bangladesh. The objective of the survey was to find out more regarding the economic condition of buffalo farmers in the Baghabari milk pocket areas of Shajadpur upazila under Sirajganj and Bera upazila under Pabna district, known as the capital of milk production in Bangladesh. Prior to conducting the survey work from April to June 2024, a questionnaire was designed and pre-tested. Five farmers from each of the ten villages that make up each Upazilla were surveyed at random. SPSS software was used to statistically analyze the collected data. According to this survey, 16% of female respondents and 84% of male respondents, respectively, reared buffalo. In the study areas, more than 80% of the farmers reared buffaloes of growing males and females (over 12 months) for fattening purpose and rest of the different population types of buffalo. Approximately 72% of farmers raised buffaloes using an intensive system, with semi-intensive systems accounting for the remaining 28%. In the surveyed areas, the majority of farmers followed a regular anthelmintic program, although about one-third of them did not vaccinate their animals. Additionally, buffalo showed a considerably higher ability for disease resistance than the cattle in the study area. Almost 60% lower health management expenses were found buffalo than cattle. More than 85% of farmers were benefited by fattening buffalo rather than dairy buffalo. The main factors limiting buffalo production in the study locations were determined to be a lack of land, water supplies, breeding bulls, breeds, and frozen semen. In light of the nation's need for safe and sustainable buffalo production, fattening buffalo might be an appropriate way to satisfy the nation's extending beef demand.

Keywords: Population, rearing system, feeding.

Productive status of buffalo at Bhola district in Bangladesh
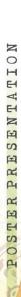
Md. Abunaser, Nirjon Sarker, Al Imran, Md. Mehedi Hasan Khandakar,
Md. Rezwanul Habib, Md. Maznu Sarkar[1], Md. Khalilur Rahman[2] and Mohammad Ashiqul Islam*

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Abstract

The study was carried out to investigate the productive performance of the buffaloes in bathan as well as in household at Bhola district in Bangladesh. Data were collected through interview of randomly selected 309 farmers from 5 sub-districts viz. Borhanuddin (n=50), Lalmohon (n=45), Char Fasson (n=121), Bhola Sadar (n=73) and Tazumuddin (n=20) of Bhola district. One-way ANOVA was performed to compare the mean of different production parameters between bathan and household as well as among the 5 sub-districts. It has been observed that approximately 85% of the farmers reared their buffaloes in bathan and 15% followed the household production system. In case of birthweight of buffalo calves, it was found significantly (P<0.05) higher in household condition (20.04 kg) than bathan system (19.30 kg).

In comparison among the five sub-districts in Bhola district, buffalo calves were born with higher birth weight at Charfassion (23 kg) than that of the others. Growth rate of buffalo was significantly (P<0.05) higher in bathan system which results in significantly (p<0.05) higher body weight at 36 month of age. Body weight at 36 month of age was found significantly (p>0.05) higher in case of buffalo reared in Tazumuddin sub-district. Daily milk yield was statistically similar (p>0.05) between bathan and household management system during 0-90 DIM. Whereas, Buffalo reared in household condition produced significantly (p<0.05) higher amount of milk daily during lactation period 3-6 month and 6-9 month. Lactation length was also significantly (p<0.05) higher in case of bathan (186 days) than that of the household system (165 days). However, lactation yield was found statistically similar (p>0.05) among these two systems. Buffalo reared in Lalmohon sub-district had highest lactation length (198 days). However, Total lactation yield was statistically similar among the buffaloes reared in different sub-districts. Finally, the data obtained in the present study could provide an insight regarding the existing production status of buffalo in Bhola district and assist the policymakers to improve the socio-economic status of buffalo farmers in this region.

Keywords: Birth weight, growth rate, daily milk yield, lactation yield.

Morphologic characteristics and productive potentialities of swamp type buffalos in Bangladesh

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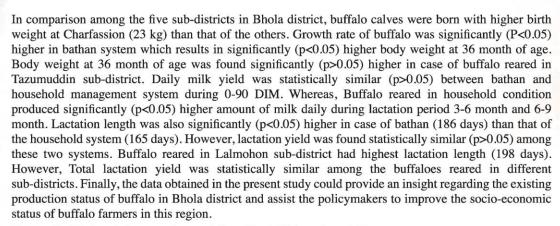
*Corresponding author: mmrahman.as@bau.edu.bd

Abstract

The study was carried out to investigate the productive performance of the buffaloes in *bathan* as well as in household at Bhola district in Bangladesh. Data were collected through interview of randomly selected 309 farmers from 5 sub-districts viz. Borhanuddin (n=50), Lalmohon (n=45), Char Fasson (n=121), Bhola Sadar (n=73) and Tazumuddin (n=20) of Bhola district. One-way ANOVA was performed to compare the mean of different production parameters between bathan and household as well as among the 5 sub-districts. It has been observed that approximately 85% of the farmers reared their buffaloes in *bathan* and 15% followed the household production system. In case of birthweight of buffalo calves, it was found significantly (P<0.05) higher in household condition (20.04 kg) than *bathan* system (19.30 kg). In comparison among the five sub-districts in Bhola district, buffalo calves were born with higher birth weight at Charfassion (23 kg) than that of the others. Growth rate of buffalo was significantly (P<0.05) higher in bathan system which results in significantly (p<0.05) higher body weight at 36 month of age. Body weight at 36 month of age was found significantly (p>0.05) higher in case of buffalo reared in Tazumuddin sub-district. Daily milk yield was statistically similar (p>0.05) between bathan and household management system during 0-90 DIM. Whereas, Buffalo reared in household condition produced significantly (p<0.05) higher amount of milk daily during lactation period 3-6 month and 6-9 month. Lactation length was also significantly (p<0.05) higher in case of bathan (186 days) than that of the household system (165 days). However, lactation yield was found statistically similar (p>0.05) among these two systems. Buffalo reared in Lalmohon sub-district had highest lactation length (198 days). However, Total lactation yield was statistically similar among the buffaloes reared in different sub-districts. Finally, the data obtained in the present study could provide an insight regarding the existing production status of buffalo in Bhola district and assist the policymakers to improve the socio-economic status of buffalo farmers in this region.

Keywords: Birth weight, growth rate, daily milk yield, lactation yield.
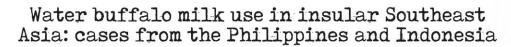
POSTER PRESENTATION

SCIENTIFIC
SESSION

PRODUCTS
PROCESSING

Water buffalo milk use in insular Southeast Asia: cases from the Philippines and Indonesia

Takashi Tsuji*

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Abstract

This study examines the uses of domestic water buffalo milk in the Philippines and Indonesia, one of the few areas where the rare practice of milking animals occurs in Insular Southeast Asia. In these countries, both milking domestic water buffalo and making milk products are practiced. Swamp buffaloes are used for milking. Fermented and heated milk products, such as cheese and candy milk are produced, probably because fresh milk risks lactose intolerance. Investigating such unique uses of milk in Insular Southeast Asia attests to an evident culture of milking domestic water buffalo in the research areas. Furthermore, although the riverine buffaloes are rapidly replacing the domestic water buffaloes, due to its higher milk yield, across Southeast Asia. It is a big concern if the water buffalo can improve the culture of the both nations to bring an equality or fairness to the small-scale farmers.

Keywords: Swamp buffalo, riverine buffalo, dairy culture, Insular Southeast Asia.

Introduction

In Southeast Asia, buffalo milk has been produced and consumed in limited parts of the Philippines and Indonesia (Tsuji et al. 2021, 2022; Tsuji 2019a, 2021a, 2021b; Hirata and Tsuji in press). This paper is focused on buffalo dairy culture in the both nations.

Buffalo is basically used for plowing agricultural field. However, this paper highlights buffalo dairy culture in the both nations which ensures livelihoods of the local people. The people have been familiar with a milk although 90% of people in Southeast Asia are suffered from lactose intolerance (Tsuji et al. 2018a; Tsuji 2021c). This paper also reports the transition of milk use in the nations.

Materials and Methods

Fieldwork in the Philippines was conducted in Bulacan province, Laguna province, Cavite province, Cebu province, Bohol province, and Samar province where native buffalo (carabao) milk use is actively practiced. The research was conducted from April 5, 2016 to March 8, 2020.
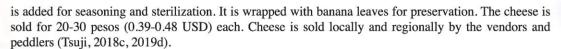
Fieldwork in Indonesia was conducted at OKI (Ogan Komering Ilir) province of Palembang, Southern Sumatra. The research was conducted from August 29 to September 1, 2019.

Research methods were observation, questionnaire, interview and measurement. In Indonesia, research was conducted with an interpreter.

Results

In the Philippines, according to records, buffalo milk use was started in Spanish colonial period (de Morga, 1966; Alcina, 2004). Farmers milk water buffalo and make a fresh cheese called kesong puti which takes the Spanish word queso as their origin (Tsuji, 2017a, 2017b, 2017c, 2017d, 2019b, 2020a) and a candy called pastillas (Tsuji, 2018a, 2018b, 2019c, 2020b). Milking is conducted early in the morning. After milking, farmers sell milk to a broker. Price of milk is typically about 100 pesos per litter (about 1.87 USD). Buffalo milk is processed into fresh cheese.

Cheese is processed using lactic acid fermentation with buffalo milk and a coconut vinegar, locally calf rennet is used but rare (Kozaki et al., 2001; Chinte-Sanchez, 2008). The milk is simmered in a pot which the temperature keeps about 70°C and add a vinegar. The milk turns to be a curd and remove a whey. Salt

KEYNOTE – PRODUCTS PROCESSING

is added for seasoning and sterilization. It is wrapped with banana leaves for preservation. The cheese is sold for 20-30 pesos (0.39-0.48 USD) each. Cheese is sold locally and regionally by the vendors and peddlers (Tsuji, 2018c, 2019d).

In Indonesia, OKI province is located in a swamp area and many native buffaloes are rearing. In rainy season, water buffaloes dive into large swamp areas for bathing and eating glasses in the swamps and people control them by using a boat. People milk around 5-7 am. Milk is sold 20,000 rupiah (1.42 USD) per cepak (equivalent to 1.25 litres).

Milk is mainly processed to gulo puan and sagon puan. Besides milking, buffalo is grown for the meat use. Gulo puan is made by simmering with buffalo milk and white sugar in a pot until it becomes solid. Sagon puan is added yolk and to simmer until it becomes powder-like condition (Tsuji et al., 2022).

The dairy products are favorite items among the people, to support their nutrition and economic lives as well.

Discussion

The native buffalo is a national symbol in the both nations. However, the new buffalo dairy culture has been introduced in the end of 20 century. In the Philippines, Philippine Carabao Center (PCC) was established as a national policy in the nation to improve the livelihoods of farmers using buffalo (Tsuji et al., 2017, 2021a).

The PCC started to loan buffalo to farmers for dairy purpose which aims to improve livelihood by loaning water buffalo to farmers and engaging in milking. The buffalo is imported from Bulgaria, Brazil, USA, Italia and India. When Murrah or hybrid births calves, farmers give them to the center to repay their loans. The PCC buys milk from the farmers and ships it to big cities. By selling milk, farmers receive a cash income. However, the farmers do not drink milk and tend to improve their livelihoods (Tsuji et al., 2018b).

Native milking water buffalo use is taking place to Murrah use in the Philippines. Preserving the gene of native water buffalo, PCC is challenging to shift from traditional milking water buffalo use to modern dairy buffalo use over the nation (Tsuji, 2021d).

On the other hand, Indonesia is also trying to increase dairy buffalo and to change the farmer's livelihood learning from the case of PCC. The government has launched the Swamp Buffalo Centre (SBC) in Palembang on 2016. In OKI province, new water buffalo milk product, jelly milk (jelly susu), has started to develop by local university, government organization and foundation involving the local people to improve nutritional condition of the children.
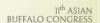
Conclusion

This paper showed unique buffalo dairy culture found in the Philippines and Indonesia. The both areas show an unusual use of buffalo for the typically non-milking cultural areas of Southeast Asia. Although this may be a product of colonialism, the people tend not to like milk probably to avoid lactose intolerant. Therefore, in the areas, a milk-drinking culture has not developed, and instead milk use has survived by converting lactose to dairy products.

Traditional buffalo dairy culture is currently undergoing dramatic changes. The Murrah will become popular in the production of milk, and in the future, the Murrah will become the center of milk use rather than the native buffalo. Crossbreeding the native buffalo and Murrah increases the production of milk in deed (Tsuji, 2021e).
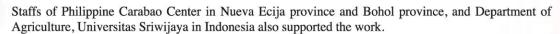
The nations were determined to improve the agricultural slump through modern buffalo milk production. New dairy culture is profit-centered and many farmers seek cash income (Tsuji, 2021f). However, the development of buffalo dairy culture is desirable and has the potential to benefit the people in the Philippines and Indonesia.

Acknowledgements

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I deeply express my gratitude for the institutions and people mentioned above.

Conflict of interest statement

The author has no conflicts of interest to disclose.

Statement on data availability

Data supporting this study are openly available from ResearchGate (https://www.researchgate.net) and researchmap (https://researchmap.jp/).

Compliance with the ethical standard

This paper does not contain any studies with human or animal subjects performed by the author. Consent for publication and transfer of copy right to the Bangladesh journal of animal science. The author hereby grants the Publisher permission to publish the work in the Bangladesh journal of animal science.

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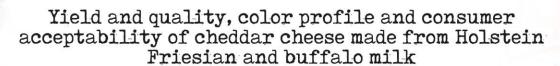
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Yield and quality, color profile and consumer acceptability of cheddar cheese made from Holstein Friesian and buffalo milk

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Abstract

Cheddar is the second-most consumed cheese in the world; however, it is not very well known in Bangladesh. In our current state of knowledge, cheddar cheese is commonly made from the milk of Holstein cows, which are known for their high milk production. Since rearing pure and crossbred Holstein cows in Bangladeshi climatic conditions is a challenging endeavor and there is no commercial utilization of buffalo milk for cheese making in Bangladesh, this study was aimed at investigating the possibility of utilizing buffalo milk as a replacement for Holstein milk in the production of cheddar cheese. The cheese yield and quality, color profile, and consumer acceptance of cheddar cheese made from Holstein Friesian and Buffalo milk were compared. After preparation, the cheese was stored for 30 days at 12°C and 85% relative humidity, and analyzed. The results revealed that the cheese made from buffalo milk had significantly ($p < 0.05$) higher amounts of cheese yield, total solids, fat, and ash than those made from Holstein milk. Interestingly, the protein% and proteolysis were significantly ($p < 0.05$) higher in Holstein milk cheddar. In the case of the color profile, the lightness (L*) was significantly ($p < 0.05$) higher in Holstein milk cheddar, while other parameters (a* and b*) remained similar ($p > 0.05$). For overall flavor, cheddar cheese intensity, and body and texture, both cheeses received almost the same score. However, in contrast to Holstein milk cheddar, buffalo milk cheddar was scored the highest for overall acceptability. In conclusion, it was evident that cheddar cheese made from buffalo milk was superior to the one made from Holstein milk in almost every regard.

Keywords: Cheddar cheese, cow milk, buffalo milk, cheese yield, quality, color profile, consumer acceptance.

Effect of carrot in fortifying block type buffalo milk processed cheese

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Abstract

Processed cheese is produced by blending shredded natural cheeses of different types and degrees of maturities with emulsifying agents and heating the blend under a partial vacuum with constant agitation until a homogenous mass is obtained. Generally, dietary fiber is absent in milk and milk products; processed cheese is not an exception. Dietary fiber lowers the risk of obesity, diabetes, cancer, and

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intestine diseases as such processed cheese is an ideal product to fortify dietary fiber food ingredients. Therefore, we consider carrot as processed cheese's external dietary fiber source. In this study, block type buffalo milk processed cheese was made by adding varying amounts of carrot (@0%, 5%, 10%, and 15%). This study aimed to assess the influence of said dietary fiber source on the physicochemical, color profile, and consumer acceptability of buffalo milk processed cheese. Results showed that with the increased level of carrot incorporation into the processed cheese, cheese yield, pH, total dietary fiber content, and water activity increased significantly ($p<0.05$); however, total solids, fat, protein, and ash content decreased significantly ($p<0.05$). With regards to the lightness (L*) and yellowness (b*) of the products, 15% carrot added processed cheese showed maximum value (83 and 54, respectively). Total solids, fat, protein, and ash were shown to be the highest in the 5% carrot addition. Moreover, 5% carrot incorporated processed cheese received the highest score in regards of taste and overall liking. The enrichment enhanced fiber and produced favorable sensory changes.

Keywords: Carrot, block type processed cheese, buffalo milk, total dietary fiber, color profile, consumer acceptance.

Reorganization of a traditional buffalo processing practice by the "meat seller caste" in Nepal

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Abstract

This presentation examines the modernization policy of the Nepalese buffalo meat industry, and how people of the Khadgi caste who had traditionally engaged in meat processing as a caste-based role accommodate with this process. Buffalo sacrifice has played a crucially important role in the rituals of the Newar, an indigenous group in Kathmandu. The distribution system for buffalo meat after sacrificial worship practices had also been deeply embedded within their caste society. Khadgis have traditionally engaged in both animal sacrifices and meat selling as their caste-based roles in Newar society. In Kathmandu Valley, almost 70% of the meat shops are owned by Khadgis. However, in 2016, the government of Nepal announced a ban on buffalo slaughter within Kathmandu Valley, deeming it "pre-modern" and "unhygienic." The meat distributors who slaughter buffaloes in a traditional manner within their residential areas are expected to convert to becoming workers in modern slaughterhouses outside the Kathmandu Valley. In response to the government policy, the Khadgis established a company in partnership with local government to provide customers healthy and hygienic meat. Khadgi has their caste association, and the association has nationwide networks. They utilized their nationwide caste network to construct a system that is compatible with both modern industrial slaughter in the plains along India/Nepal boarders and traditional hand slaughtering in the Kathmandu Valley. In the meat market, the Khadgi negotiate beyond their caste and ethnicity, especially with the Muslim community, who play a leading role in the global meat market. Simultaneously, they maintain their caste-based traditional butchery to provide buffalo raw meat and intestines especially for rituals. Consequently, this presentation reports how the Khadgi reorganized buffalo processing industry in adapting tactically to state-instituted modernization.

Keywords: Meat processing, caste, traditional butchery, modernization of meat industry, public health.

Buffalo milk processing and marketing in the coastal area of Bangladesh

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Abstract

The south and southeast parts of Bangladesh are known as the coastal zone, being surrounded by the Bay of Bengal. In this coastal zone, buffalo is the most resilient mammalian species, capable of surviving in salinity and tidal waves. Buffalo is the native animal species in the coastal region of Bangladesh and is reared under semi-intensive system in the upper part and nomadic system in the lower part, especially on the off-shore islands. Approximately 90% of the total dairy buffaloes of Bangladesh are reared in the coastal region. There is no official statistics on the actual milk yield of buffaloes in this region. However, the demand of buffalo milk is very high as evident from the buffalo milk price. Buffalo milk is sold on an average @Tk140/kg in this region whereas the milk is sold on an average @Tk. 80-100/kg in the plain land of the country. This is due to buffalo milk utilization and marketing system. The coastal region has its own culture that includes the consumption of yogurt made through indigenous and traditional technique. Buffalo milk is mainly used for preparation of yogurt by traditional milk processor commonly known as "Ghosh". A small portion of buffalo milk is also used for the preparation of curd which is further processed into soft cheese or sweetmeats. Buffalo milk is not sold to processing company; instead, it is sold to Ghosh. The Ghosh typically pay a fixed price for the milk to the buffalo owners for the entire year and transport the milk from offshore islands by boat. Therefore, the marketing and processing of buffalo milk in the offshore islands are closely linked to the Ghosh and local culture.

Keywords: Coastal region, buffalo milk, marketing, processing.

ORAL PRESENTATION

Effect of fortification of rasomalai and processed cheese using non-dairy ingredients on physicochemical, color and consumer likings

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Abstract

The study aimed to assess the physicochemical, color, and sensory evaluation of diverse rasomalai and processed cheese made from buffalo milk by adding non-dairy ingredients- flaxseed and walnut. Rasomalai is prepared by cooking channa ball, made of acid coagulated milk curd into sugar syrup and finally immersed into the heat concentrated milk i.e., malai. Processed cheese is usually made up by cooking different varieties of cheese along with emulsifier including different dairy and non-dairy ingredients. Flaxseed and walnut were separately added to rasomalai and processed cheese @ 1% and 3% in paste form. Physiochemical analysis revealed that the ash content of processed cheese and rasomalai differs significantly ($p < 0.05$). The addition of flaxseed and walnut causes enhancement in the fat content of both products. The crude protein content was found higher in both products when 3% of flaxseed and walnut were added. In sensory analysis, 1% walnut-added processed cheese and flaxseed-added rasomalai showed the best results for overall liking, texture, and flavor. Walnut-added processed cheese received a significantly ($p < 0.05$) higher overall appearance, whereas, the appearance of rasomalai was unaffected when added flaxseed. Instrumental color tests showed significant ($p < 0.05$) effect on both products with walnut and flaxseed. The 3% walnut-added processed cheese had the highest lightness (88), whereas, 3% flaxseed-added rasomalai has the lowest (84). Gradual increases of redness and yellowness in both products were found with different percentages of walnut and flaxseed. Giving the priority on the consumer acceptance we recommend the addition level of flaxseed and walnut should be 1% in rasomalai and processed cheese. These findings suggest opportunities to incorporate dairy products with various non-dairy ingredients for enhancing nutritive value and consumer acceptance.

Keywords: Rasomalai, processed cheese, fortification, walnut, flaxseed.

An innovative utilization of expired buffalo milk casein in sustainable and biodegradable food packaging

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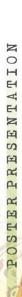
Abstract
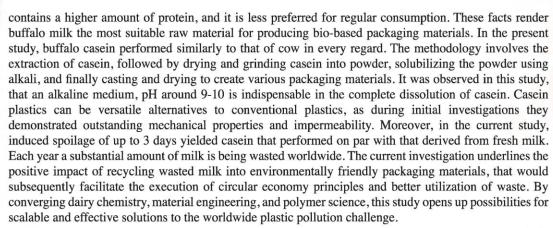
The prevailing concerns about the negative impacts of petroleum-based plastics on the environment and human health mandate immediate action. Similarly, the progressive increase in food waste, along with their improper disposal, is another pressing issue faced globally. This study intends to tackle both of the problems and develop a sustainable alternative to conventional plastics that would not only be environmentally friendly but also safe for food-related applications. Compared to cow milk, buffalo milk

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contains a higher amount of protein, and it is less preferred for regular consumption. These facts render buffalo milk the most suitable raw material for producing bio-based packaging materials. In the present study, buffalo casein performed similarly to that of cow in every regard. The methodology involves the extraction of casein, followed by drying and grinding casein into powder, solubilizing the powder using alkali, and finally casting and drying to create various packaging materials. It was observed in this study, that an alkaline medium, pH around 9-10 is indispensable in the complete dissolution of casein. Casein plastics can be versatile alternatives to conventional plastics, as during initial investigations they demonstrated outstanding mechanical properties and impermeability. Moreover, in the current study, induced spoilage of up to 3 days yielded casein that performed on par with that derived from fresh milk. Each year a substantial amount of milk is being wasted worldwide. The current investigation underlines the positive impact of recycling wasted milk into environmentally friendly packaging materials, that would subsequently facilitate the execution of circular economy principles and better utilization of waste. By converging dairy chemistry, material engineering, and polymer science, this study opens up possibilities for scalable and effective solutions to the worldwide plastic pollution challenge.

Keywords: Food waste, circular economy, sustainable packaging, casein plastics, dairy waste recycling.

The attributes of buffalo milk over cow milk: a review

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Abstract

Buffalo milk is an ideal, complete, and healthy diet contributing 12% of the total milk production worldwide. It is a richer source of nutrients, containing 17.65% total solids, 7.52% fat, 5.33% carbohydrates, 4.02% protein, and 0.80% ash, all dissolved in 82.33% water. The fat globules (5µm) of buffalo milk is larger than cow milk which aids in cream separation, and the production of butter, ghee, cheese, and ice cream. In addition, buffalo milk has a higher tocopherol content (334.21 μg per kg) as compared to cow milk (312.3μg per kg) associating high peroxidase activity. Casein, a significant protein source, constitutes about 89% of the total protein content in buffalo milk. With a higher lactose content (5.02%) than cow milk (4.70%), buffalo milk is considered as a valuable source of energy. In terms of mineral content, buffalo milk provides more calcium (0.16%), phosphorus (0.11%) and potassium (0.17%) compared to cow milk, which contains 0.12%, 0.09%, and 0.15%, respectively. Buffalo milk is also richer in vitamin A across all seasons, with the concentrations of 67.1 µg in winter, 73.3 µg in spring, 48.1 µg in summer, and 48.4 µg in autumn per 100 ml of milk. The vitamin B12 found four times higher in buffalo milk over cow milk. It also contains higher levels of vitamin E (5.5 mg in buffalo and 2.1 mg in cow per 100 ml) and C (3.66 mg in buffalo and 0.94 mg in cow per 100 ml). Buffalo milk has antioxidant properties for the presence of higher monounsaturated fatty acids (MUFA), small amounts of phenolic compounds, fat-soluble vitamins (A & E) and minerals. In addition, the availability of A2 allele in indigenous buffalo breeds ensures A2A2 milk production results human health benefits against type I diabetes, lactose intolerance, arteriosclerosis, schizophrenia, autism etc.

Keywords: Ideal food, chemical composition, fat, minerals, health benefit.

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Major objectives of the Project

a) To increase milk production of indigenous river buffaloes through selective breeding
b) To evaluate the productivity of Murrah×Indigenous F1 crossbred buffalo
c) To adopt Murrah buffaloes in Bangladesh
d) To develop technologies for profitable buffalo farming

Buffalo Research and Development Project
Bangladesh Livestock Research Institute, Savar, Dhaka
Ministry of Fisheries and Livestock

Grameen Jano Unnayan Sangstha (GJUS)

Actively involved in buffalo development and improvement of livelihood in the coastal areas of Bangladesh

Buffalo Breeding Farm

Buffalo Killa in an offshore Iland

Activities
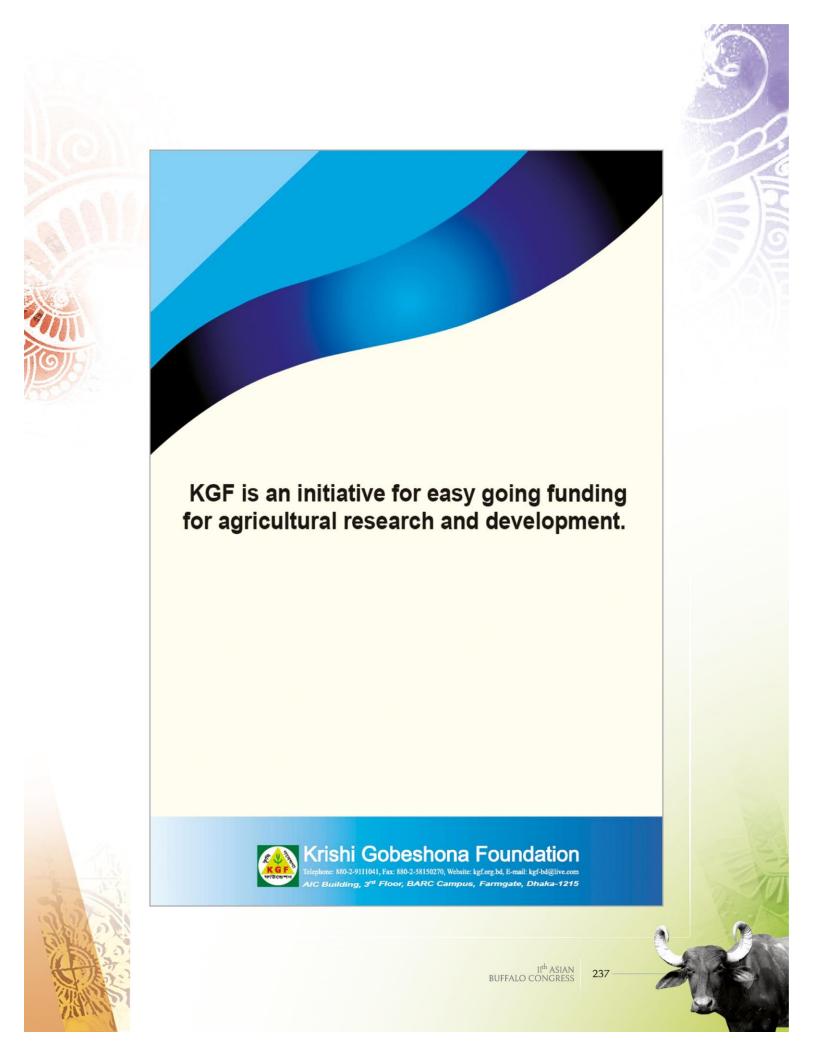
1. Buffalo Breeding Farm establishment.
2. Establishment of buffalo shelter (Killa)
3. Killa wise service center development
4. Training on modern technology & Product diversifications
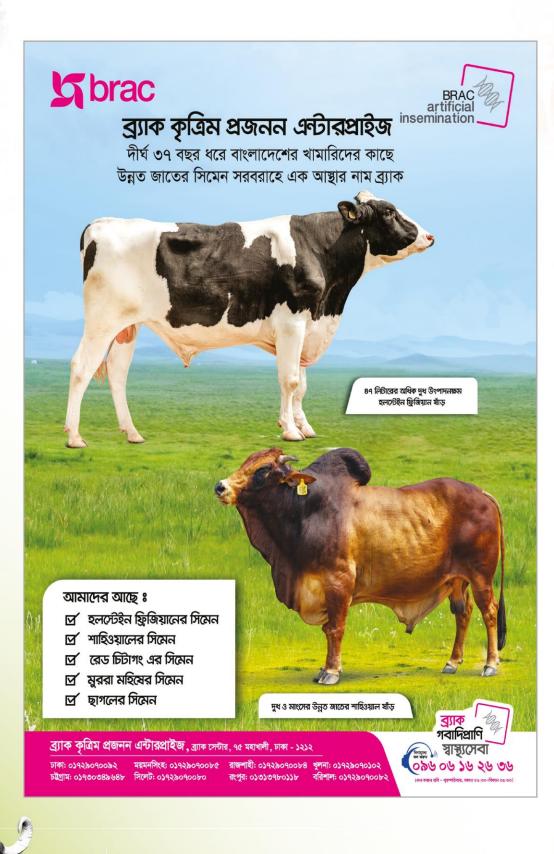5. Sustainable Technology for this coastal area are developed.

Grameen Jano Unnayan Sangstha (GJUS)

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মহিষ ও গরুর দুধের মধ্যে গুণগত মানের তুলনা

মহিষ	গরু
ফ্যাট এর পরিমাণ বেশি (গড়ে ৬.৯%)	ফ্যাট এর পরিমাণ কম (গড়ে ৩.৫%)
ক্যালরি এর পরিমাণ বেশি (১০২%)	ক্যালরি এর পরিমাণ কম (৬১%)
প্রোটিন এর পরিমাণ বেশি (৩.৭%)	প্রোটিন এর পরিমাণ কম (৩.৩৪%)
ভিটামিন ও মিনারেল এর পরিমাণ বেশি (০.৭%)	ভিটামিন ও মিনারেল এর পরিমাণ তুলনামূলক কম (০.৬%)
কোলেস্টেরল এর পরিমাণ কম (০.৬৫ মি. গ্রা.)	কোলেস্টেরল এর পরিমাণ বেশি (৩.১৪ মি. গ্রা.)
বেশি ঘনত্ব	তুলনামূলক পাতলা
সংরক্ষণকাল বেশি	সংরক্ষণকাল তুলনামূলক কম
বিটা ক্যারোটিনের পরিমাণ বেশি তাই দুধের রঙ সাদা	বিটা ক্যারোটিনের পরিমাণ কম তাই দুধের রঙ তুলনামূলক হলদেটে

মহিষ ও গরুর মাংসের মধ্যে গুণগত মানের তুলনা

মহিষ	গরু
মহিষের মাংসে গরুর তুলনায় কার্যকর আয়রন পরিমাণ বেশি থাকে (১.৪ মি. গ্রা.)	গরুর মাংসে মহিষের তুলনায় কার্যকর আয়রন পরিমাণ কম থাকে (১.২ মি. গ্রা.)
কোলেস্টেরল এর পরিমাণ কম (৩৫%)	কোলেস্টেরল এর পরিমাণ বেশি (৮০%)
মহিষের মাংসে চর্বির পরিমাণ মাত্র ২ শতাংশ	গরুর মাংসে চর্বির পরিমাণ ১৫ থেকে ২০ শতাংশ
মহিষের মাংসে ভিটামিন বি-১২ এর পরিমান অনেক বেশি যা শিশুদের দৈহিক বৃদ্ধি ও মানসিক বৃদ্ধি ঘটায়	গরুর মাংসে ভিটামিন বি-১২ এর পরিমান তুলনামূলক কম
মহিষের মাংসে আমিষ (২৪%) ও মিনারেল (৬৪১মি. গ্রা.) বেশি থাকে	গরুর মাংসে আমিষ (২২%) ও মিনারেল (৫৮৩ মি. গ্রা.) কম থাকে
গরুর চেয়ে মহিষের মাংস পুষ্টিগুণ অনেক বেশি	মহিষের চেয়ে গরুর মাংস পুষ্টিগুণ কম

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ময়মনসিংহ: ০১৭৩০০০৪৯৪৮, বগুড়া: ০১৭৩০০০৪৮৩১, যশোর: ০১৭৩০০০৪৮৩৫, চট্টগ্রাম: ০১৭৩০০০৪৮৩৪, ঢাকা: ০১৩১৩০৯৩৬৯৬

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