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A SYSTEMATIC REVIEW OF RESEARCH FINDINGS ON BUFFALO HEALTH AND PRODUCTION PUBLISHED DURING THE LAST SIX DECADES IN BANGLADESH

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ABSTRACT

Background: A large number of indiscriminate research reports on buffaloes have been published from Bangladesh but a systematic review based on these findings is lacking in literature. This review was conducted to analyze and summarize all the available inland research reports on buffaloes to identify gaps and to provide recommendations that would be required for future academic and research plan for buffalo development.

Objective: The purpose of this review was to assess and provide the research progress on buffaloes to maximize the direction and benefits for the future academicians, research scientists, producers and consumers.

Materials and Methods: A comprehensive scientific literature search on all the aspects of buffaloes published in peer-reviewed journals from Bangladesh was reviewed during two years periods of 2018 to 2019.

Results: Bangladesh has only 1.485 million indigenous buffaloes distributed throughout the country with higher concentration (40%) in coastal districts and some buffalo pockets. A limited number of imported Nili-Ravi and Murrah buffaloes and their crosses are reared in some farms and smallholder farmers in Bangladesh. Buffalo has been 'undervalued' and not addressed properly for development in Bangladesh. Most of the indigenous buffaloes are reared with very minimum housing facilities and limited feed supply. Some farmers are usually supplied local grass (4.98 ± 2.89 kg/DM/day) and rice straw (10.90 ± 2.85 kg DM/day) with one or two concentrate feed (1.51 ± 0.80 kg/DM/day) in their lactating buffaloes. Natural breeding (95.7%) is more prominent practice than AI (4.3%). The buffalo breeders and farmers are facing challenges in terms of poor reproductive efficiency, sub-optimal production potential, lack of feed and fodders, infertility and high calf mortality. However, a total of 236 research reports have been reviewed on buffaloes, which 126 on production and 110 on health aspects. The research on productive and reproductive performances, live weight and meat production, feeds and feeding, balanced rations for calves and lactating cows have been reviewed and described. The buffalo health research includes on anatomy, histology, physiology, biochemistry, microbiology, parasitology, pathology and clinical sciences with emphasis to toxoascariasis, mastitis, rotavirus and calf mortality have been described and discussed.

Conclusions: The demand of draught animals at rural level decreased due to mechanization whereas the demand of animal sources protein (milk & meat) increased tremendously due to urbanization. Therefore, there is a great scope for dairy buffalo production side by side cattle dairy industry in Bangladesh. The indigenous buffaloes with poor reproductive and productive performances need to be improved through upgrading the genetic improvement by AI with Nili-Ravi and Murrah buffalo semen and adequate provision of feed and fodder with balanced ration, better management practices, adequate veterinary medical services with appropriate extension are required for dairy buffalo production in Bangladesh. An attempt at government level and concerned scientists would be required to solve the seven recognized constraints related to buffalo production and health to promote the livelihood of smallholder farmer's via-a-vis national economy of Bangladesh.

Keywords: Buffalo health and production, Last six decades, Research findings, Systematic review, Bangladesh

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INTRODUCTION

Buffaloes 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 transportation, dung as fuel and organic fertilizer, livelihoods and nutrition of poor households and hides and skin as raw material for industry.[1,2] Murrah and Nili-Ravi buffaloes are called as 'Black gold' in Haryana (India) and Pakistan respectively because of their versatile qualities especially high milk yield.[3,4] The overall percentage of buffalo milk production is about 51.2% in India, 59.5% in Pakistan, 66.6% in Nepal, 18.0% in Sri Lanka whereas in Bangladesh it is only 1.4%.[5-10] The domesticated water buffalo is often referred to as the 'living tractor of the East' since it is relied upon for ploughing and transportation in many parts of Asia.[7] All buffaloes belong to the *Bovidae* family and domestic buffalo (*Bubalus bubalis*) is also known as water buffalo which is divided into two sub-species: river buffalo (*Bubalus bubalis bubalis*) and swamp buffalo (*Bubalus bubalis carabensis*), being morphologically and genetically distinct with different chromosome number. The River buffalo has 50 chromosomes and Swamp buffalo has 48 chromosomes.[11] The water buffalo is the largest buffalo and even the largest of all members of the family *Bovidae* which are distributed mainly in the tropical and sub-tropical Asia.[12] The Cape buffalo (*Syncerus caffer caffer*) is also known as African buffalo because it can be found all over Sub-Saharan Africa that occurs naturally.[13] The Asian buffalo includes three species: (a) Indonesian Anora (*Bubalus depressicornis*), (b) Tamaraw (*Bubalus mindorensis*) of Philippines and (c) Asian buffalo (*Bubalus bubalis*) domesticated from wild Asian buffalo (*Bubalus arnee*).[11] Each sub-species includes many breeds and presently, there are 72 buffalo breeds in the world, from which 57 in Asia and 20 in India, with most popular are the Murrah, Nili-Ravi, Surti and Jaffarabadi in Indian sub-continent for their high milk production.[6,8] Bangladesh has only 1.485 million buffaloes which are mostly indigenous origin and both the Swamp and River types are found throughout the country.[14,15] The concentration of buffalo population is higher in coastal part (about 40%), Meghna-Ganga and Jamuna-Brahamaputra flood plain, subsequently forming buffalo pockets in Bangladesh.[15-17] In addition, Kanihari buffalo pocket is situated in Mymensingh district.[18] Buffalo in Bangladesh is the next to the cattle that has for a long time contributing to the smallholder farmers 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. These animals are used as a draught animal and partially for milk and meat production.[6,7,15] The contribution of buffalo is about 1.4% in total milk and 0.9545% in meat production in Bangladesh.[6,7,9] However, the buffalo production has always been neglected despite of its importance of smallholder farmers' livelihood and national economy.[6,7] The major problems of buffalo farmers in Bangladesh have been reported to be lack of feeds and fodder, lack of grazing land, lack of fresh water during flood, lack of veterinary medical facilities, lack of high quality breeds, lack of natural service and AI and lack of government support.[19] Water buffalo is known for its rusticity and great adaptability to different topographies, soils and climate but they can still be afflicted with various diseases and disorders that greatly affect their production performance and even cause mortality.[20] However, the indiscriminately published research reports on buffalo production and

health are voluminous and some review reports on buffalo production in Bangladesh compared to SAARC,[6,7] genetic resources and their conservation,[14] dairy buffalo production scenario,[8] scopes and opportunities of buffalo farming[6,7] are available but no attempt has been made to review and unify the research findings on both the buffalo production and health aspects in Bangladesh. Therefore, this comprehensive review of research reports on both the buffalo production and health would certainly provide a guideline for the design of future research and validating the existing research findings. This paper summarizes research developments on buffaloes since 1966 to unearth the present scenario of buffalo production, benefits and values of buffalo milk and meat, advantages of buffalo farming over cattle, constraints buffalo production especially breeds, nutrition and diseases and recommendations for future academic, research and buffalo development plan in Bangladesh.

MATERIALS AND METHODS

The research reports on buffalo production and health published mainly in journals during the last six decades from 1966 to 2019 from Bangladesh were reviewed and analyzed. Google Scholar, PubMed, Research Gate, Bangladesh Journal-Online (BJO) and directory of open access journals were searched using relevant keywords to identify articles. However, the BJO website has established in 2007 and accordingly the journals and their published articles are uploaded on their webpages from 2008 without any archive of the articles published before 2008. Different libraries searched results reveals that the related journals in which articles on different aspects of buffaloes have been published before the year 2008 from the then East Pakistan and Bangladesh are mostly somehow displaced and lost in antiquity. Accordingly, articles which were published from 1966 to 2007 were reviewed from the BAU central library, Faculty of Veterinary Science and Faculty of Animal Husbandry libraries, personal collection sources, different journal editorial offices and even request to the authors during the two years period from 2018 to 2019. Data obtained from the different reports were statistically analyzed by using Chi-square test for significance (SPSS version 17.0).

RESULTS AND DISCUSSION

The current world human population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100.[21] Therefore, the global food securities especially livestock products are an important agricultural commodity because they provide 33% of global protein consumption and 17% of global kilocalorie consumption.[22] The livestock sector generated employment for about 1.1 billion people and contributed to the livelihoods of one billion of the poorest population in the world.[23] World meat production will double from 258 to 455 million tons and milk production is expected to increase from 664 to 1077 million tons from 2006 to 2015.[24]

The world buffalo population is estimated to be 198.88 million, spreading across 42 countries, of which 96.4% are distributed in Asia, 2.9% in Africa, and rest in Europe and Latin America.[25] The ranking of buffalo producing countries highest in India (115.4 million), followed by China (46.50 million), Pakistan (32.7 million), Nepal (5.10 million) and Egypt (3.9 million) in the

world,[2] whereas Bangladesh has only 1.485 million buffaloes.[15] River buffaloes (primarily dairy and secondary draught with higher live weight of 450-1000 kg) are distributed in Bangladesh, India, Iran, Iraq, Nepal, Pakistan, Sri Lanka and some European countries like Italy, Bulgaria, Greece and Yugoslavia, whereas swamp buffaloes (primarily draught and secondarily dairy with lower live weight of 325-450 kg) are distributed in Bangladesh, Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, Philippines, Thailand and Vietnam.[26,27]

Buffaloes have a number of advantages over cattle which include well-adapted to harsh environment and known to have a better capacity of converting poor-quality roughage especially agricultural crop residues and by-products (coarse feed stuffs) into milk and meat, more disease resistance ability and produce more solids in milk and require less management inputs.[28-30] They are reported to have a 5% higher digestibility of crude fiber than high-yielding cows and a 4-5% higher efficiency of utilization of metabolic energy for milk production.[11] Indigenous buffaloes are three times heavier than indigenous cattle and produce two times more milk than indigenous cattle.[19] Buffalo milk contains less water, more total solids, fat and protein than cow's milk which is excellent for the preparation of dairy products like curds, cheese ('mozzarella cheese'), butter, butter oil (ghee) and yogurt. However, the buffalo population is very low in Bangladesh compared to the 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 to the people regarding the buffalo milk and meat preferences with cattle.[31] Therefore, the constraints of buffalo production especially veterinary medical extension services, upgrading of indigenous buffaloes, health and disease management, feeds and management practices for the improvement of milk and meat production at both the smallholder farmer's and bathan rearing systems would be required.

Types and breeds of buffaloes

Water buffalo have historically been divided into swamp and river buffalo based on morphological, behavioral and geographical criteria. The two types also differ in chromosome number: swamp 2n= 48 and river 2n = 50[32,33] because of a telomere-centromere tandem fusion between two chromosomes in river buffalo.[34] The river (*Bubalus bubalis bubalis*) and swamp (*Bubalus bubalis carabensis*) buffaloes are sometimes referred to as sub-species. Swamp buffalo are found throughout Southeast Asia and China. There are no recognized breeds and they are reported to be mainly used as draught animals and their milk yield is low. River buffalo are mainly found in the Indian subcontinent and westwards through Southwestern Asia and Mediterranean countries. These are recently introduced to Africa, South America and Australia.[35] Well-recognized and morphologically defined river buffalo breeds exist in India and Pakistan but 70% of river buffalo do not belong to any named breed and are classified as non-descriptive.[36] The geographical ranges of river and swamp buffalo overlap in East India and Bangladesh.[35]

There is no recognized breed of buffalo in Bangladesh but different types of indigenous buffaloes and some crosses are found throughout the country (Table 1). The predominant

Table 1. Types and breeds of buffaloes found in Bangladesh[6,7]

SNTypes / Breed	Regions (Table 2)	Population	Genotype and phenotype
1. Indigenous (River)	Western & Central parts	433000	Medium size, Jet black to black Chromosome 50
2. Indigenous (Swamp)	Eastern part	37500	Small size, grey, chevron & white, Crescent horns, Chromosome 48
3. Bangladeshi	Central & South West	4500	Medium size, Light black, chevron & white stocking, Chromosome 50
4. Non-descriptive	South west & Southern parts	207569	-
5. Cross-bred*	Southern part, Indian borders	40000	Medium size, Phenotypes based on original breeds
6. Nili-Ravi	Buffalo Breeding Farm, Bagherhat	60	Nili-Ravi breeds' characteristics

*Local × Murrah, Local × Nili-Ravi, Local × Surti and Local × Jaffrabadi - = Not available

indigenous buffaloes (*Bubalus bubalis*) are river type distributed throughout Bangladesh with exception of some low productive swamp type in in Eastern part.[16,37,38] However, some imported breeds including Murrah, Nili-Ravi, Surti, Jaffrabadi and Munipuri and their crosses are also available mainly surrounding Indian border due to boarder migration from India to Bangladesh.[6,7,39] The buffaloes are concentrated particularly in agro-ecological zones of sugar-cane belt, hilly region, coastal area and marshy land.[17] The dairy buffaloes are distributed along the riverside village of Rangpur, Bogra, Jamalpur and Mymensingh districts. They are also distributed in coastal areas of Noakhali, Feni, Laxmipur, Bhola, Patuakhali and Borguna districts.[14] Draught buffaloes are distributed in sugar-cane belt and forest areas-like Jamalpur and Modhupur.[17]

The indigenous buffaloes can be grouped into five types based on the basis of their history of domestication, distribution and morphology which include: ① Indigenous buffaloes in the eastern part, ② Indigenous buffaloes in the western part, ③ Indigenous buffaloes in the central part, ④ Indigenous buffaloes in the southern part and ⑤ Exotic (Nili-Ravi) and their crosses with indigenous (Table 2).[6,7]

The Department of Livestock Services (DLS) imported some Nili-Ravi breed of buffalo from Pakistan in 1960 to supply breeding bulls to the farmers in the coastal area of Southern part for cross-breeding purposes. The DLS again imported 100 Nili-Ravi pregnant heifers and first lactating cows from Pakistan during 1990 that were reared in newly established Buffalo Farm at Bagherhat district, in south-west part in Bangladesh (Table 2). In addition, Murrah buffalo breed has been used for up-gradation of indigenous buffaloes. Recently, buffalo development project is started since 2010 where cross-breeding of indigenous buffaloes with Italian Mediterranean semen in limited area using AI in 39 upazillas of 13 districts (Table 2). In addition, there are few buffalo pockets in Bangladesh including coastal area, Sylhet haor area, sugar cane belt of Jamalpur and Kanihari buffalo pocket in Trishal Upazila of Mymensingh

Table 2. Distribution of indigenous buffaloes in different regions in Bangladesh[14]

SN	Types of buffaloes with regions	Districts	Characteristic morphology	Milk yield/ lactation	Gestation length (day)
1.	Indigenous buffaloes in the eastern part (Swamp type)	Greater Sylhet, Chittagong & Sunamgonj (Marshy land)	•Usually gray & crescent horns •Most of the buffaloes have chevrons and white stocking •Some water buffaloes have white flecks on each side of the face	272-300 kg	240-270
2.	Indigenous buffaloes in the western part (Indigenous Murrah type)	Rajshahi, Natore, Naogan, Bogra	•Black coat color & curly horns •Some have brown coat color with spot on the tail switch •Some buffaloes have hanging horns •These are largest buffaloes in BD •Males are used for draught, meat and female buffaloes for dairy purposes	620 kg	270
3.	Indigenous buffaloes in the central part (Indigenous Riverine type)	Brammaputra & Jamuna belt Rajshahi, Jessore, Rangpur, Bogra, Pabna, Jamalpur, Mymensingh	•Morphological features are almost similar to those of the western part • The coat color is usually black •They are kept for dual purposes, male for meat and females for dairy	990 kg	274
4.	Indigenous buffaloes in the southern part (Wild type Arni/ Cross-bred type)	Coastal areas Noakhali, Feni, Laxmipur, Bhola, Patuakhali, Khulna, Barguna, Pirojpur, Chittagong	•In addition to indigenous crossbred (Local x Nili-Ravi) buffaloes constitutes 15% of the coastal buffalo population •They are larger in size than indigenous buffaloes in this coastal area. •Their milk yield is 2-3 times higher than indigenous buffaloes.	-	-
5.	Exotic breed and their crosses with local (Murrah, Nili-Ravi, Surti, Jaffrabadi)	-	•Nili-Ravi breed of buffalo was first imported from Pakistan in 1960s and then in 1990 for crossbreeding program •Recently Murrah breed of buffaloes has imported from India, although it already exists in border areas.	-	-

- = Data not available

district sole used for milk production over 100 of years (Table 3).[18] There are approximately 10,500 buffaloes in the New Sandwip Island of which 75% native (deshi)-Swamp type, 19% crossbred (Deshi x Murrah or Deshi x Swamp) and 6.0% Murrah buffaloes.[40]

It appears that the buffalo breed improvement programs have been conducted for the genetic improvement of indigenous buffalo populations several times but none of the initiatives were satisfactory due to lack of organized plans.[31] Recently, Milk-vita has imported 200 Murrah milking buffaloes with calf from Haryana, India with BDT 5.6 crores under the total project cost of 18.23 crores.[41] The Milk-Vita received their first consignment of 100 buffaloes on May and second consignment on Thursday 19 July 2018.[42,43] Milk-vita has established two mother

Table 3. Morphological characterization of buffaloes in Kanihari buffalo pocket[18]

Type/ Group	Local name	Coat color	Horn pattern	Population (%)	Farmer's preference (%)
Type-1	Gurjuti	Jet black, soft, smooth & scanty hair	Short, tightly curled & forming coil	20.14	35.0
Type-2	Nepali	Fawn or black, rusty Brown hair & black or white switch	Short to medium in size & sickle shaped	43.24	45.0
Type-3	Deshi (milk type)	Black	Comparatively large, no definite shape	36.62	20.0
Overall				100	100

buffalo farms one at Takerhat, Madaripur and other one at Raipur, Laxmipur consisting 100 milking buffaloes each. The goal of the project is to popularize dairy Murrah buffalo to cooperative farmers along with their existing dairy cattle.

Purposes of buffalo rearing and farming

Buffalo is a triple purpose animal which provides milk, meat and draught power for humans. Buffalo offers immense potential for the improvement of livelihood through its high nutritious milk, leaner meat and best draught power for wet environment.[26] The purposes of rearing buffaloes are varied from areas to areas and types of buffaloes raised but primarily for milk and meat purposes. A study in Noakhali showed 100% farmers rear buffaloes to earn money through sale of milk and live buffaloes.[44] Approximately 50% smallholder buffalo farmers reared buffaloes for self-employment and improve livelihood, 20% for solely self-employment, 20% for solely milk production, 18% to improve livelihood and 5% for an additional income by producing milk and meat.[45] However, only < 5% farmers used their buffaloes for draft purposes mainly to carry the homestead goods along with milk production. However, draught use buffaloes often affect their production and reproduction performances.[46] Buffalo as a draft animal has working capacity of 0.75 H.P. and a sturdy buffalo can pull a weight of 0.9 to 1.0 ton.[47] In the bathan system of rearing, buffaloes are reared for mostly meat production in which milk yield is considered as an extra income.[45] Overall 33.3% used for milk and meat, 13.5% for milk and draught, 43.6% for draught and 9.59% for milk, meat and draught purposes in Bangladesh.[46] Therefore, there is a huge scope to increase milk and meat production by developing our native buffaloes through cross-breeding program with Murrah and Nili-Ravi breeds of buffaloes.

Buffalo production system in Bangladesh

The buffalo production system is mainly based on the topography, vegetation patterns and seasonal availability of the feed resources with low input. Buffaloes are raised throughout Bangladesh with some specific distribution of concentration in coastal saline region, plain land, marshy land and hilly areas which is fully depends on the availability of feed resources.[6,7] Buffaloes are reared under major four production systems based on land areas and types:

(a) Household subsistence farming, (b) Semi-intensive farming and (c) Intensive system farming and (d) Extensive system.

(a) **Household subsistence farming** - usually 1 to 3 with maximum 10 buffaloes are raised under stall feeding with 6 to 7 hours grazing in and around backyard or public land with very little feed supply. Household buffalo farming is practice close to marshy land area, heavy draft required (inland forest, sugarcane cultivation and remote rural areas) and upper land to coastal areas.[31] Buffaloes are mainly raised in homestead farming in Tangail, Jamalpur, Bogra, Sirajgonj, Pabna and Thakurgaon districts.

(b) **Semi-intensive farming**- usually 4 to 15 buffaloes are reared in combination of seasonal based household during rice cultivation and free range system during common land free which is mostly upper part of coastal regions. Buffaloes are raised under semi-intensive system on plain land and marshy land where there is a limited pasturing in common land and road sides.[31]

(c) **Intensive rearing system** has been started at the Bangladesh Buffalo Center of Lal Teer Livestock Limited, Government Buffalo Breeding Farm, Bagherhat and Bangladesh Livestock Research Institute, Savar, Dhaka.[31]

(d) **Extensive farming system** (EFS) - usually 51- 200 with maximum of 600 buffaloes are raised completely under natural grazing system with almost no extra feed supply. The extensive farming in bathan in coastal region includes offshore islands, mudflats, chars (accreted land), new accretions and river basin areas, where large scale open pasture land and seasonal green forages are available.[31] The bathan (extensive free range rearing) systems are mainly reared in Bhola, Noakhali, Lakshmipur and Patuakhali districts in Bangladesh.[45] Approximately 91% farmers keep their buffaloes under open sky at night, 5% under the tree and 3% under the roof at night in Noakhali.[44]

Buffalo breeding system and genome research

Naturally the buffalo breed throughout the year and produce two calves every three years.[27] Genetic diversity, problems and prospect of breeding, selective breeding and record keeping have been utilized in buffalo breeding in Bangladesh.[48-51] However, the reproductive and productive performances are influenced by genotype, nutrition, management and climate. The artificial insemination (AI) is the most widely used technique for dissemination of superior genetic material of outstanding males in breeding system of ruminant animals. Superior male germ-plasm identification and its propagation are of utmost importance for breed improvement. However, the AI is the normal practice in cattle breeding but it is still limited in buffaloes due to the poor estrus expression that cause difficulties in the estrus detection and variability of estrus length and variable time of ovulation that make the difficulties in finding an adequate moment for AI.[52,53] This has led to the use of timed inseminations procedures at many locations, yet the overall coverage of buffaloes with AI continues to be low. The natural service is mainly performed in buffaloes in all over the country except in intensive buffalo farming in Bangladesh.[49-51,54] Some preliminary studies on semen collection and influence of multiple showering on quality of buffalo semen during hot-humid season in Bangladesh have been evaluated.[55] Murrah and Nili-Ravi breeds have been used to upgrade the indigenous buffaloes

in Bangladesh. Bangladesh Buffalo Center of Lal Teer Livestock Limited is practicing artificial insemination (AI) and synchronization in their intensive buffalo farms since 2010. The highest pregnancy rate (60%) has been reported in buffaloes inseminated between 12-18 hours after ovulation (estrus), followed by 6-12 hours (50.0%), 18-24 hours (10.0%) and 0% when inseminated between 0 to 6 hours after 1st signs of estrus in buffaloes.[56] The high yielding improved frozen buffalo semen marketing has been started to some household farming and semi-intensive farming system by Bangladesh Livestock Research Institute (BLRI) to develop buffalo in Bangladesh through their AI activities in the field.[31] However, assisted reproductive technologies like AI and embryo transfer have also been introduced and implemented in buffalo production with less success due to the reproductive seasonality and the time and effort required to perform estrus detection have limited. Therefore, synchronization of ovulation for the fixed-time AI (FTAI) during the breeding season has been suggested an alternative technique which allows AI without the need of estrus detection. Each buffalo received 10 µg of Buserelin (GnRH) during the post-partum period (average 60 days), then seven days later, the animal received $PGF_2\alpha$, then two days after $PGF_2\alpha$ administration, buffaloes received 10 µg of GnRH and then were inseminated 16 hours later resulted acceptable pregnancy rate.[53] This synchronization protocols permits the use of AI throughout the year with satisfactory levels of conception and calving even in anestrus buffalo during the off breeding season.[53] However, most of the buffaloes are reared under the smallholder farming system in Bangladesh and therefore future research should focus on simple, adoptable and impact-oriented approaches to identify the risk factors of low fertility, estrus behavior and AI in buffaloes.[57] Moreover, the genome science can be applied to provide knowledge and technologies to enhance the production potential to the optimum level, improve reproduction efficiency and increase disease resistance in buffaloes.[58-60]

Milk production performance

Cattle, buffaloes and goats are considered as dairy animals, of which about 90% milk is producing from cattle, 6-7% from goats and the remaining 3-4% from buffaloes.[6,7] There are 18 breeds of river buffaloes, of which Murrah, Nili-Ravi, Mediterranean and Jaffrabadi are mainly reared for milk production with a daily 6 to 7 liters of milk. The lactation length is about 300 days in the Murrah breed and about 320 days in the Nili-Ravi breed. Milk yield ranges from 1500 to 1800 kg for the first lactation with a steady increase to a peak in the fourth lactation. Thus, a buffalo could be retained in the herd up to about ninth lactation (16 years of age) with reasonable economic returns.[27] However, the Haryana' murrah buffalo yields 32.6 kg milk per day that sets world record.[61] Officials said earlier this record was held by a buffalo from Pakistan which had given 32.50 liters of milk.[61]

Buffalo milk has higher levels of fat, lactose, protein, ash and calcium and vitamin A and C and lower levels of vitamin E, riboflavin and cholesterol as compared to cow milk[62,63] and so it can be considered as more nutritious for human health. The buffalo milk is healthy as it is richer in saturated fatty acids. The lower water and higher fat contents make buffalo milk better suited for the manufacture of fat-based and solid not-fat (SNF) based milk products like cheese, butterfat, ice cream, ghee and milk powder.[64] Swamp buffalo milk has higher fat (9-15%),

protein (7.1%), lactose (4.9%) and ash (0.89%) contents. Ca, Fe, and P contents are higher in buffalo milk than in cow milk. The lower cholesterol content in buffalo milk should make it more popular than cow milk in the health conscious public.[27] The fat globules in buffalo milk are bigger than in bovine milk with 60% having size between 3.5 to 7.5 µm[65] and even much larger diameter of 8.7 µm in buffalo milk than cow fat globules of 3.95µm have been reported.[66] Buffalo milk contains 275 mg cholesterol whereas cow milk contains 330 mg.[67]

Milk is a very complex product and it provides essential nutrients and is an important source of dietary energy, protein, fats and minerals (Table 4). It also contains pigments, enzymes, vitamins, phospholipids and gases. When water and gases are removed from milk is called the dry matter (DM) or total solids content of the milk. The genetic (species, breed), physiological (age, stage of lactation, parity, farming system, physical environment, season), nutritional and farming system influence the color, flavor and composition of milk. Table 4 shows the comparison of milk composition of different species of animals with women.

The buffalo dairy in South East Asia is characterized by small scale, scattered and unorganized buffalo holders, low productivity, inadequate and inappropriate animal feeding and health care. Low productivity of dairy buffaloes is serious constraint to dairy development in the region. The productivity of dairy buffaloes could be increased by adoptive appropriate breeding strategies.[9]

Table 4. Comparison of milk composition of different species[6,7,68,69]

SN	Constituents	Unit	Woman	Mare	Donkey	Buffalo	Cow	Goat	Sheep
01.	TDM	g/100g	10-13	09-12	08-12	12.81-19.63 15.60 ± 2.55	12-13	12-16	18-20
02.	Water	g/100g	-	-	-	81.1	87.8	88.9	83.0
03.	Fat	g/100g	2.1-4.0	0.4-7.2	0.3-1.8	5.3-15.0 (8.0)	3.3-6.4 (3.9)	3.0-7.2 (3.5)	4.9-9.0 (6.0)
04.	Protein	g/100g	0.9-1.9	1.3-2.0	1.4-2.0	2.7-4.7 (4.5)	3.0-4.0 (3.2)	3.0-5.2 (3.1)	4.5-7.0 (5.4)
05.	Lactose	g/ 100g	6.3-7.0 (-)	6.0-7.2 (-)	5.8-7.4 (-)	3.2-4.9 (4.9)	4.4-5.6 (4.8)	3.2-4.5 (4.4)	4.1-5.9 (5.1)
06.	Ash	g/100g	0.2-0.3	0.3-0.5	0.3-0.5	0.53-0.90*	0.7-0.8	0.7-0.9	0.8-1.0
07.	SNF	%	-	-	-	7.52-9.35**	-	-	-
08.	Energy	kj/100g	270-209	109-210	160-180	420-480	270-280	280-290	410-440
09.	Calcium	mg/100g	-	-	-	195	120	100	170
10.	Phosphorus	mg/100g	-	-	-	130	90	120	-
11.	Cholesterol	mg/100g	-	-	-	8	14	10	11

TDM = Total dry matter SNF = Solid-not-fat *Mean value (0.62 ± 0.06) **Mean value (8.30 ± 0.54)

Table 5 shows buffalo milk production and marketing in Bangladesh. The total milk production per day, per lactation and lactation period varied on different management systems (smallholder & bathan) and genotypes (indigenous and cross-bred) of dairy buffaloes have also been reviewed. The buffaloes raised under household (semi-intensive system) produced higher milk than those raised under bathan (extensive system) which might be due to lack of feeding

concentrate to the buffaloes raised in the bathan.[45] Table 6 shows that the quality of swamp buffalo milk is superior to that of water buffalo milk based on constituents of milk.[70]

Table 5. Buffalo milk production and marketing [45]

S/N	Parameters	Sub-level	Respondents (%) Household	Bathan
1.	No. of milking	1/day	33	87
		2/day	67	13
2.	Milk yield / animal /day (liter)	1-2	20	74
		>2-5	38	26
		>5	42	0
3.	Milk marketing channel	TMM	17	58
		FMP	17	37
		FSLM	13	05
		FCSLM	53	ND

TMM = Through middle men
FMP = Farmer to milk processor
FSLM = Farmer sale at local market
FCSLM = Family consumption and sale at local market
ND = No data

Table 6. Comparison of composition of buffalo milk[70]

S/N	Constituents	Water buffaloes (n = 3)	Swamp buffaloes (n = 3)
1.	Fat (g/kg)	72.67 ± 0.58	84.25 ± 0.25**
2.	Total solids (g/kg)	167.00 ± 0.02	176.46 ± 0.35 **
3.	SNF (g/kg)	92.20 ± 0.19	94.80 ± 0.15**
4.	Protein (g/kg)	37.67 ± 0.26	39.68 ± 0.06**
5.	Lactose (g/kg)	47.55 ± 0.18	48.00 ± 0.10*
6.	Ash (g/kg)	07.07 ± 0.02	07.13 ± 0.00
7.	Acidity (%)	0.155 ± 0.00	0.164 ± 0.00
8.	Water (g/kg)	832.97 ± 0.06	826.60 ± 5.55
9.	pH	06.52 ± 0.12	6.37 ± 0.02

n = No. of lactating buffaloes
SNF = Solid not fat
Data = Mean ± SD
*Significant at ($p < 0.05$)
**Significant at ($p < 0.01$)

The daily milk production of Bangladeshi indigenous buffalo is usually varied from 2.70-2.89 liters,[71] however comparatively higher milk production of 3.33-3.43 liters per day have also been reported in indigenous buffaloes.[72] Total milk production per lactation of Nili-Ravi and cross-bred buffaloes ranged from 620-1161 kg with a lactation length of 270-330 days.[73] Comparatively lower milk production of 542 liters by 290 days has also been reported.[74]

The higher daily average 2.27 liter with 878 liters lactation milk yield by 387 days have been reported in indigenous Murrah type buffaloes (Table 7). However, lower milk yield of 1.65 liter per day with a total of 504 liters in 305 days with 8.6% fat and 3.9% protein have been reported in wild Arini type buffaloes.[31,75]

Table 7. Meat and milk production of buffaloes in Bangladesh[31,75]

SNTypes of buffaloes	Average body weight (kg)				Average milk production and its attributes*				
	At birth		Adult		Milk yield /day (liter)	Lactation length (day)	Lactation yield (liter)	Fat (%)	Protein (%)
	Male	Female	Male	Female					
1.IM	30	27	550	450	2.27	387	878	7.2	3.9
2.IPLRT	31.33	26	490	400	1.93	289	558	9.1	3.6
3.WTA/C	29	27	512	433	1.65	306	504	8.6	3.9

IM = Indigenous Murrah IPLRT = Indigenous plain land riverine type WTA/C = Wild type Arni/ Crosses
*Population not available

An average lactation yield of buffaloes has been reported to be 730 kg during 328 days lactation period where fat in milk has to range from 6.8 to 13.2%. Daily milk yield of buffalo (2 to 3.5 L) has been reported lower than crossbred cows (3.5-7.0 L) but higher than indigenous cow.[16] As buffaloes have higher milk production than local cattle which indicates higher potentiality of buffalo for diminishing gaps of milk production in Bangladesh. The indigenous water buffaloes produced average 2.29 ± 0.56 liter milk per cow at test day whereas 2.98 ± 0.05 liter per cow the mean peak milk yield in Noakhali.[44] However, the average milk production of 2.7 liter per day per buffalo cow[71] and 600 to 1000 liter milk production for a lactation period of 250-270 days have also been reported.[16] The 42% buffalo farmers reported peak milk production in second month of lactation period and 48% farmers reported highest milk production in second parity.[44] The poor genotype, limited feed availability, inadequate health care service, lack of cold chain, poor transportation and unorganized marketing system are the main constraints in dairy industry in Bangladesh.[76] The variations of milk yield and lactation length in different genotypes of buffaloes are the important factors for future research to establish the breeding policy in sustainable buffalo production in Bangladesh.

Total demand of 15.03 million MT milk and 7.21 million MT meat in Bangladesh, whereas deficit of 5.62 million MT milk but surplus of 0.046 million MT meat have been reported in Bangladesh.[15] However, these estimated values contradict with the other published reports with milk and meat status in Bangladesh. It has been reported that the Bangladesh will face a 6 million MT shortage of milk in 2021, whereas based on the recommended intake of milk (200-250ml or 15-20g milk powder), domestic production is only able to make up 62.6% of the needed supply.[77] It has also been reported that the production of milk unable to meet local demand because Bangladesh has imported almost doubled its powder milk.[78]

Productive and reproductive performances

Reproductive efficiency is the primary factor affecting productivity and is hampered in the female buffalo by a delayed attainment of puberty, seasonality, long post-partum anestrus and subsequent calving interval and poor estrus expression.[47] Buffaloes are raised primarily for draught purpose or dairy and meat production is a secondary option in Bangladesh. Puberty in buffalo is delayed compared with cattle. The age at puberty is difficult to establish because of difficulties in estrus detection in buffaloes and most estimations appear to have been extrapolated from the age at first calving.[47] Review on published inland research reports on productive and reproductive performances of different types of buffaloes shows great variation on the parameters used. Table 8 shows the average values on reproductive performances of different types of buffaloes in Bangladesh.

It appears from Table 8 that the age of first heat (1440 days) and first calving (1770 days) have been reported higher in indigenous plain land riverine type buffalo than indigenous Murrah (1080 & 1440 days) and wild type Arni / crosses (1050 & 1410) buffaloes,[75,79] whereas service per conception and dry period have reported lower as 1.25 and 216 days in riverine buffaloes. The indigenous male buffalo attained puberty at 3 years of age.[16] Average of 2.6 ml semen per ejaculation with concentration @ 1080 million / ml in buffalo has been reported.[52]

Table 8. Average values on reproductive performances of buffaloes in Bangladesh[75,79]

SNParameters	Indigenous Murrah	Indigenous plain land Riverine type	Wild type Arni / crosses	Cross-bred (Local x Mediterranean)
1. Age at maturity (days)	1080	1440	1050	-
2. Age at first calving (days)	1440	1770	1410	-
3. Calving interval (days)	559	573	582	-
4. Service / conception (No.)	1.7	1.25	2.5	-
5. Gestation length (days)	304	306	304	-
6. Dry period (days)	234	216	218	-
7. Average semen volume (ml)	-	2.6	-	3.8
8. Sperm conc. @ million/ml)	-	1216	-	1080

- = Data not available

There is a large variation in age at puberty of buffaloes in different breeds and countries. They delay in puberty and the consequent delay in conception is one of the problems that lead to the low reproductive efficiency of the buffalo species.[47] Risk factors influence age at puberty which include breed, season, climate, nutrition and growth. The buffalo management needs right from birth to ensure a correct weight increase because the animals that show a higher daily gain reach puberty in a shorter time.[47] The indigenous buffaloes of Bangladesh reached sexual maturity at 1411 days of age[16] which is higher length in comparison to the report of 1241 days.[71]

Table 9 shows the overall mean productive and reproductive performances of different types of buffaloes. The productive and reproductive performances are the important considerations to determine the profitability of buffaloes, which influences the economics of milk production in dairy animals. The productive and reproductive parameters are maintained to increase the milk production per animal.

Average daily milk yield

The average milk yield of buffaloes during lactation period which can be measured in liter / day by using the formula: Average milk yield (liter/day) = Lactation yield ÷ 305 days.[80] The milk yield is the main output which has the economic significance in milk production. An effort has been made to find out the average daily milk yield in different types of buffaloes by analysis of 10 inland reports in Bangladesh (Table 9). It appears that Murrah (3.85 L/d) produced highest daily milk yield, followed by Nili-Ravi (3.41 L/d) in comparison to other breeds of buffaloes (Table 9). Reviewed of five inland reports showed 3.02 liters an average daily milk production in buffaloes in Bangladesh.[14]

Lactation length (period)

The lactation length of buffaloes is a number of days a buffalo remain in milk from the date of calving to the date of start of dry.[80] The optimum lactation length of dairy buffalo is one of the best indicators in the performances of the dairy animals. Analysis of findings of 10 inland reports reveals that the highest lactation length was found in Nili-Ravi (260.59 days) in

comparison to Murrah (250.88 days) and other types of buffaloes (Table 9). Analysis of four inland reports showed an average of 303.94 days lactation length in buffaloes in Bangladesh.[14]

Lactational milk yield

The lactational milk yield is conceptualized as the average total quantity of milk produced by buffalo in its lactation period which is calculated as: Lactation milk yield (liter) = Peak milk yield × 200.[80] Lactation milk yield has been reported to be 799 liters in a lactation length of 270 days in buffaloes in Bangladesh.[45] A wide range lactation length from 150 to 270 days with lactation milk yield varied from 196 to 916 liter with an average of 469.52 ± 163.71 liter have been reported in smallholder buffaloes in Bangladesh.[69] The milk yield of water buffaloes has been reported to be varied from 620 to 1161 kg in 270 to 330 days[7] with an average of 730 kg during 328 days lactation period[16] whereas reviewed of only two inland reports showed an average of 664.03 liter lactation milk yield.[14]

Dry period

The dry period is the period from the date of drying (stop of milk production i.e. rest period) for the dairy animal and her udder before the next lactation (calving). The buffalo and her udder are prepared for the next lactation during dry period. The buffalo should be dried off approximately 2 to 3 months before expected calving with traditionally considered 60 to 150

Table 9. Overall productive and reproductive performances of buffaloes in Bangladesh

SN Parameters	Types and breeds of buffaloes										Ref. Nos.
	Local (L)		Cross (C)		Mixed (L + C)		Nili-Ravi		Murrah		
	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	
01. Milk yield (liter/day)	885	1.53	169	2.38	510	2.94	17	3.41	170	3.85	a (10)
02. Lactation length (days)	885	230.56	169	246.51	510	206.44	17	260.59	170	250.88	b (10)
03. Age at 1st heat (days)	885	1032	169	1042	1072	1268	17	1024	170	1036	c (10)
04. Estrus cycle length (days)	885	21.88	169	21.91	-	-	17	21.18	170	21.66	86 (01)
05. Estrus duration (hours)	885	24.68	169	23.90	-	-	17	23.47	170	23.13	86 (01)
06. AI after onset of estrus (hrs)	885	11.80	169	11.59	-	-	17	11.59	170	11.50	86 (01)
07. Age at 1st pregnancy (year)	-	-	-	-	140	3.52	-	-	-	-	69,71,84
08. Age at 1st calving (days)	885	1384	169	1397	712	1606	17	1412	170	1397	d (11)
09. No. of service /conception	885	1.64	169	1.78	1666	2.11	17	1.88	170	1.38	e (09)
10. Gestation length (days)	885	312.15	169	313.40	670	312	17	314.47	170	313.68	f (10)
11. Post-partum heat (days)	-	-	-	-	1116	146.61	-	-	-	-	g (13)
12. Calving interval (days)	885	580.8	169	581.1	1394	493.62	17	582.3	170	549.3	h (11)
13. VWP (days)	885	66.92	169	65.41	-	-	17	68.12	170	64.87	86
14. Birth weight (kg)	180	24.22	100	30.5	-	-	-	-	-	-	72,82-85

n = No. of buffaloes () = No. of reports

VWP = Voluntary waiting period can be defined as the interval during the post-partum period in which producers decide not to breed cows even if estrus occurs.

a = 44-46, 69, 72, 82-86 b = 44-46, 69, 72, 82-86 c = 16,44-46, 71, 84-88

d = 16, 69, 71, 72, 82-88 e = 16, 45, 46, 69, 71, 84, 86-88 f = 16,45,69,71, 72, 82-86

g = 16, 45, 46, 69, 71, 72, 82-85, 87, 88 h = 16, 45, 46, 69, 71, 72, 82-88

days but the dry period more than 60 days in high yielding buffalo has been reported to be not advantageous and would be costly affair for the farmers in both productive and reproductive backdrop.[81] It appears from Table 8 that the average dry periods varied in different types of buffaloes like indigenous murrah (234 days), indigenous plain land riverine type (216 days) and wild type arni / cross-bred (218 days) buffaloes have been reported.[75,79] However, lower dry period ranged from 30 to 90 with an average of 42.80 ± 26.44 days has also been reported under semi-intensive system in Bangladesh.[69]

Age at first heat (sexual maturity)

Analysis of 10 published research reports on age at first heat reveals that higher average age of 1268 days was found in mixed (local & cross) type in comparison to local (1032 days), cross (1042 days / 42.27 months), Nili-Ravi (1024 days / 34.13 months) and Murrah (1036 days/ 34.53 months) buffaloes (Table 9). These findings are in support with 34.41 ± 2.02 months in local, 34.74 ± 1.81 months in cross-bred, 34.12 ± 1.65 months in Nili-Ravi and 34.53 ± 1.96 months in Murrah buffaloes.[86] Analysis of three inland reports showed 43.56 months (3.58 years) age at first heat (sexual maturity) in buffalo heifers in Bangladesh.[14] It also compares well with 36 to 42 months age of puberty in buffaloes in India.[89] However, the age at puberty is influenced by genotype, nutrition, management and climate and under favorable conditions occurs at 15 to 18 months in river buffaloes and 21 to 24 months in swamp buffaloes.[90] Delayed maturity in buffaloes is common in Bangladesh mainly due to an inadequate supply of feed and nutrients to calves during their growing period. Well-fed buffalo heifers are suitable for breeding at about 24 months of age but in majority of dairy buffaloes calving occur at 4 to 6 years of age.

Estrus cycle length and duration

Only one report has recorded estrus cycle length in buffaloes in Bangladesh with non-significant differences among local (21.88 ± 1.93 days), cross-bred (21.91 ± 1.49 days), Nili-Ravi (21.18 ± 1.47 days) and Murrah (21.66 ± 1.83 days) buffaloes.[86] The higher estrus duration has been reported in local (24.68 ± 3.01 hours) in comparison to cross-bred (23.90 ± 2.96 hours), Nili-Ravi (23.47 ± 1.55 hours) and Murrah (23.13 ± 2.97 hours) buffaloes.[86] These findings support the Indian report of 21 days length of estrus cycle in buffaloes with heat duration 12 to 24 hours.[89]

Age at first pregnancy

Analysis of the available three inland reports on the age at first pregnancy showed 4.52 years age required for first pregnancy in buffaloes in Bangladesh (Table 9). However, 3.81 years has also been reported for first pregnancy in buffaloes in Bangladesh.[14]

Age at first calving

The age of first calving is the actual age (months/days) of buffaloes at the time of its first calving. Lower the age of first calving is considered the better performances of dairy animals.[80] Analysis of the findings of the 11 reports reveal that the average age of first calving (first calving age) varied in different types of buffaloes like local (1384 days / 46.13 months), cross-

bred (1397 days / 46.57 months), local and cross mixed (1606 days / 53.53 months), Nili-Ravi (1412 days / 47.07 months) and Murrah (1397 days / 46.57 months) buffaloes (Table 9). The average age at first calving of indigenous buffalo has been reported as 50.88 ± 1.71 months in Pirojpur and 51.00 ± 1.0 months in Borguna districts but analysis of 11 such inland reports show 50.17 months age of first calving in buffaloes in Bangladesh.[14] However, these findings are in conformity with the reported average first calving age of local (46.12 ± 1.66 months), cross-bred (46.56 ± 1.64 months), Nili-Ravi (47.06 ± 1.64 months) and Murrah (46.56 ± 1.46 months) buffaloes.[86]

Insemination time after onset of estrus

Table 9 shows the results of AI in different types of buffaloes after onset of estrus in Bangladesh. Non-significant differences of insemination time after onset of estrus have been reported among the local (11.80 ± 0.81 hours), cross-bred (11.59 ± 0.86 hours), Nili-Ravi (11.59 ± 0.71 hours) and Murrah (11.50 ± 1.02 hours) buffaloes (Table 9).[86] However, the pregnancy rates varied significantly in buffaloes inseminated at different stages of estrus with 0% inseminated between 0-6 hours, 50% between > 6 - 12 hours, 60% between >12-18 hours and 10% between >18-24 hours after onset of estrus signs.[56] These results are in conformity of the time of ovulation between 10 to 14 hours after the end of estrus in Indian buffaloes.[89] However, these findings contradict with higher pregnancy rate reported at 24 hours (53.0%) compared to 0 hour (26%), 12 hours (37%) and 36 hours (13%) of estrus time in Nili-Ravi buffaloes.[91]

Service per conception

The service per conception is defined as an average number of insemination or natural service required by a buffalo to become pregnant. Analysis of the findings of nine reports shows that the average number of services per conception have some similarities in different types of buffaloes which includes 1.64 in local, 1.78 in cross, 2.11 in local and cross mixed, Nili-Ravi 1.88 and Murrah 1.38 (Table 9). These findings are in support with an average of number of service per conception of 1.64 ± 0.78 in local, 1.78 ± 1.26 in cross-bred, 1.88 ± 0.70 in Nili-Ravi and 1.38 ± 0.59 in Murrah buffaloes.[86] However, higher number of service per conception of 2.396 has been reported based on analysis of five inland reports.[14]

Gestation length

Analysis of the 10 available reports on gestation length of buffaloes reveal non-significant differences of gestation length among the different types of buffaloes like local (312.15 days), cross-bred (313.40 days), local and cross mixed (312 days), Nili-Ravi (314.47 days) and Murrah (313.68 days) buffaloes (Table 9). These findings are in conformity with an average gestation period of 312.15 ± 12.04 days in local, 313.40 ± 4.97 days in cross-bred, 314.47 ± 3.78 days in Nili-Ravi and 313.68 ± 4.70 days in Murrah buffaloes.[86] However, comparatively lower an average gestation period of 309.596 days based on analysis of five inland reports[14] and 310 days in Indian buffaloes.[89] Gestation averaged 308.7 ± 0.4 days and ranged from 275 to 346 days in length with 57.2% buffaloes calved from 305 to 314 days after AI have been

reported in Nili-Ravi buffaloes from Pakistan.[92] The sires, dams and months of breeding have been recognized as the risk factors for gestation length and birth weight of calves.

Post-partum heat

Analysis of post-partum heat of 1116 different types of buffaloes in 13 inland research reports showed an average of 146.61 days of post-partum heat in buffaloes (Table 9). Comparatively higher post-partum estrus of an average of 158.472 days has been reported based on analysis of such five inland reports.[14] However, the post-partum have been reported between 44 and 87 days elsewhere, and reports from Egypt, India and Pakistan showed that only 34 to 49% of buffaloes showed estrus during the first 90 days after calving and 31 to 42% remained anestrus for more than 150 days.[93] The role of suckling, nutrition, body condition score at calving, milk yield, parity, season of calving and other minor factors have been reported to be associated with post-partum heat in buffaloes.

Calving interval

The calving interval is the period (days) between two successive calving that is the period between the calving of the first calf to the calving of immediate next calf. One fertile female buffalo should have at least one calf for every 15 months. If the calving interval is increased, the total number of calvings in her life time will be decreased and also total life milk production decreased. Analysis of the results of 11 inland reports reveal that the average intercalving period found comparatively higher in local (580.8 days /19.36 months), cross-bred (581.1 days / 19.37 months) and Nili-Ravi (582.3 days / 19.41 months) than the mixed with local and cross (493.62 days /16.45 months) and Murrah (549.3 days /18.31 months) buffaloes (Table 9). These findings are in conformity with an average calving interval of 19.36 ± 2.39 months in local, 19.37 ± 2.63 months in cross-bred, 19.41 ± 1.66 months in Nili-Ravi and 18.31 ± 1.97 months in Murrah buffaloes.[86] However, lower calving interval of 500.14 days (16.67 months) has also been reported in buffaloes based on analysis of six inland reports.[14]

Detection of estrus and early pregnancy

The words ‘estrus’ and ‘estrous’ look and sound similar but ‘estrus’ (commonly called heat) is a noun and refers to the short period in which a cow is sexually receptive and will stand to be bred. ‘Estrous’ is an adjective used to describe things related to estrus such as the behaviors associated with estrus (estrous behaviors) or the period from one estrus to the next (estrous cycle).[94] Only two inland available articles on the estimation of estrogen and progesterone for the detection of estrus and early pregnancy in buffaloes from Bangladesh have been reviewed.[86,95] In the first report, milk progesterone has been used to detect early pregnancy in buffaloes (Table 10). It has been concluded that the early pregnancy in buffaloes can be diagnosed based on higher milk progesterone concentration but it may complicate with uterine infection.[95] In the second report, comparative blood estrogen and progesterone levels have been detected in different types and breeds of buffaloes at the time of artificial insemination (Table 11) without any future application and interpretation of findings.[86]

The plasma estradiol 17-β level has shown to be gradually increased and peak at 0 day of estrus (25.41 pg/ml) and then significantly decreased at +1 (3.21 pg/ml) and at +2 (2.72 pg/ml),

Table 10. Milk progesterone (ng/ml) at estrus and post AI in buffaloes[95]

Buffalo ID	Day 0	Day 12	Day 22	Buffalo ID	Day 0	Day 12	Day 22
09*	0.06	2.01	1.44	20	0.52	0.89	0.53
21	0.06	0.36	0.63	24*	0.33	2.41	2.71
29	0.20	0.61	0.18	30	0.52	1.02	0.54
31	0.06	0.41	0.68	32**	0.28	1.41	1.32
33	0.33	0.32	0.33	34	0.10	2.38	0.82

*Pregnant **Buffalo with pyometra

Table 11. Comparative blood hormonal levels at the time of AI in estrus buffaloes in Bangladesh[86]

SNParameters	Types and breeds of buffaloes (n = 112)*							
	Local (L)		Cross (C)		Nili-Ravi		Murrah	
	n	Mean	n	Mean	n	Mean	n	Mean
1. Estrogen (pg/ml)	-	15.56±8.77	-	18.77±11.15	-	12.71 ± 9.82	-	17.32 ±9.95
2. Progesterone (ng/ml)	-	1.10 ± 0.65	-	1.02 ± 0.55	-	1.34 ± 0.59	-	1.07 ± 0.74

*Type and breed-wise population tested are not available in the article n = No. of animals - = Not available

whereas the plasma progesterone levels has been reported to be lowest during the peri-estrus at -2 day (0.30 ng/ml) to 0 day (0.09 ng/ml) of estrus and then increased through the early luteal phase at + 2 day (0.27 ng/ml).[96] Accurately predict the stage of estrus (heat) is required to achieve appropriate timing of natural service or insemination which is the biggest restriction in attaining high conception rate in dairy herd. The estrous cycle is complex and regulated by several hormones and organs, which is similar in both cattle and buffaloes and the regular cycle is usually 21 days with range of 18 to 24 days. Estrogen induces behavioral signs of estrus by its action on the central nervous symptoms. Estrus concides with a peak in estrogen (15-25 pg/ml) level produced by the dominant follicle causes the animal to show signs of estrus. Ovulation usually takes place towards the end of estrus except cattle and buffaloes where it takes place about 10 to 12 hours after the end of estrus.[97] Cattle and buffaloes can be bred on the day of lowest progesterone to achieve adequate fertility.[98] Estimation of ovulation time is based on the progesterone estimation in blood and milk and ultrasound monitoring of ovary and reproductive tracts. ELISA based determination of pre-ovulatory estradiol in raw milk sample is precise method to describe buffalo cows in heat along with progesterone detection.[99] The time of peak estrogen secretion can last from 6 to 24 hours with ovulation occurring 24 to 32 hours after the beginning of estrus.[100] The progesterone levels are four to five times higher in milk than those in blood plasma[101,102] and non-pregnant buffaloes can be detected on 21 days after AI by estimation of progesterone.[103]

Delayed maturity, silent heat, poor expression of estrus, irregular estrous cycle, seasonality in breeding, low conception rate and long post-partum interval are some of the major constraints in buffalo productivity. Therefore, a sound knowledge of reproductive functioning in terms of

interplay of hypothamic, gonadotropic and gonadal hormones with synergistic and antagonistic influences from other hormones and factors involved in the regulation of various reproductive stages, accurate estrus detection on non-conceived stock can be expected to lead to an improvement of the reproductive efficiency.[96,104]

Early pregnancy (embryonic period usually 42 days of post-AI) diagnosis is the key to shorten the calving interval through early identification of non-pregnant animals and their timely treatment and rebreeding so as to maintain a post-partum barren interval close to 60 days.

Measurement of progesterone is an indirect method for early pregnancy diagnosis. Estrus cycle indicate that the milk or serum progesterone concentrations reach a maximum level 13-14 days after estrus and if the animal is pregnant, these continue to remain elevated up to day 21 after fertilization and beyond. These high levels of progesterone in serum or milk between days 18 and 24 after AI form the basis of establishment of pregnancy in cattle and buffaloes. Although low progesterone concentrations at 18 to 24 days after breeding can accurately predict non-pregnancy however, high progesterone concentrations during this period are not the specific indicators of pregnancy due to variations among cows in duration of the estrus cycle as well as the incidence of early or late embryonic death.[105]

Several methods of early pregnancy diagnosis are being practiced in cattle and buffaloes, yet none qualifies as the ideal pregnancy diagnosis method due to the inherent limitations of sensitivity, accuracy, specificity, speed and ease of performing the test. The advancement of molecular techniques like proteomics and their applications in animal research has given a new hope to look for pregnancy biomarker molecules in these animals but this technique is still in their infancy in animal science research.[105]

Live weight and meat production of buffaloes

The birth weight of native buffalo calves varied from 22 to 29.80 kg[72] but it has been reported to be 36.50kg in crossbred buffaloes.[74] The birth weight, growth rate per day and weight up to 9 months of crossbred buffaloes varied 37.41 kg, 691-736 g and 224-239kg,[75] whereas 28-29kg, 464-503g and 153-165kg for indigenous buffaloes reared in confined areas.[74] Table 9 shows that an average 24.22 kg and 30.5 kg live weight of local and cross-bred buffalo calves based on analysis of five inland reports on the birth weight of buffalo calves.[72,82-85] Adult body weight of indigenous buffaloes have been reported to be 427 kg including growth rate per day 360 and 353 g respectively.[74]

The intensive buffalo farm for meat production has not yet been established commercially in Bangladesh. Meat animals are usually used culled buffaloes from different management systems. Buffalo meat is almost similar to beef in terms of composition, quality, and organoleptic characteristics and has an added advantage of less fat, cholesterol and calories. However, buffalo meat is dark red in color because of less intramuscular fat and more pigmentation. Buffalo meat has also superior processing characteristics and is suitable for development of value-added meat products.[2] The quality of buffalo meat depends on type and breed of buffaloes, age, feeding and management system, health and environmental conditions. Most of the buffaloes are slaughtered at old age when their whole life in works and animals are usually very emaciated.

Feeds and feeding of buffaloes

Buffaloes are mostly found in countries where feeds, fodders and pastures are limited and are of poor quality like Bangladesh. In spite of this situation, the buffaloes have thrived reasonably well and relatively better than cattle.[47] Buffaloes are known to be better ability to utilize poor-quality coarse feeds, straws and crop residues converting them into milk and meat. Growing buffaloes may utilize coarse feed more efficiently than cattle, more disease resistance ability, produce more solids in milk and require less management inputs.[28,29,106] They have reported to have a 5% higher digestibility of crude fiber than high-yielding cows and 4 to 5% higher efficiency of utilization of metabolic energy for milk production. However, at similar feeding and management condition, buffaloes are relatively better nutrient utilizer, grow faster and efficient converter of feed than cattle.[29]Accordingly, buffaloes fit well in poor countries like Bangladesh having poor feed resources.

It is well established that the main cost of livestock production is in feed and it accounts more than 70% of total production cost. Approximately 87% household buffalo farmers and 90% bathan farming system, depend to feed their animals on public land.[45]

The staple feed for buffalo is the rice straw and road side grass, rice field grazing, elephant grass, sugarcane leaves, cassava leaves, rice bran, wheat bran, pulse bran, boiled broken rice, maize stover, crushed maize, oil cakes, mineral and vitamin supplement are offered to intensive and household dairy buffaloes in Bangladesh.[31] The smallholder farmers are mainly used crop's residues as feed materials for the buffaloes. Dry roughages straw, grazing in common land and some concentrates ingredients like wheat bran, rice bran and pulse bran. Small green grasses are available from rice field, road side grass and char land grazing. In Bagherhat district, the buffalo farmers fed their animals with locally available roughages (51.7%), cultivated fodder (21.7%) and tree leaves (26.7) but they did not practice concentrate feeding.[107] However, farmers are not aware about nutritional requirement of their buffaloes and even research and evaluation of the nutritional requirement at different stages of reproductive cycles have not been studied.

Table 12 shows some research findings on feeds and feeding trials in buffaloes of Bangladesh. The calcium and phosphorus supplementations have been suggested to be required for milk production in dairy buffaloes and about 2% bone meal has been reported superior than 1% bone meal supplementation.[108] The mustard oil cake, til oil cake and the feeding of groundnut oil cake have been reported to be more beneficial to improve the constituents of milk in lactating Murrah buffaloes.[109] Feeding of urea up to 1% of dry matter of locally available feedstuffs as a source of non-protein nitrogen has been reported to be beneficial in growing young male buffaloes.[110] The 4.0% urea treated straw either ensiling or soaking in urea-water showed increased intake of straw, increased feed digestibility and weight gain in buffalo heifers when compared to untreated straw.[111] Feeding of rice straw soaked in urea water supplemented with a mixture of broken rice (100/200 g) and fish meal (300/600 g) improved the digestibility and live weight gain of buffalo calves.[112] Feeding of urea ensiled straw (7.3 kg) and 4.0% urea soaked straw (7.0kg) increased dry matter intake, digestibility, growth rate, live weight and feed efficiency in both the groups but comparatively higher digestibility and growth rates in feeding urea ensiled straw.[113] Feeding of urea or urea-molasses treated rice straw showed no

Table 12. Main findings of research on feeds and feeding trials in buffaloes in Bangladesh

SN	Buffaloes	Feed composition	Main results / Benefits	Ref. Nos.
A.Use of Bone meal supplement				
01	-	2% bone meal	Caused high milk fat & total solids	108
B. Comparison among three oil cakes on milk production				
01	-	Mustard / Til / Groundnut oil cake	Groundnut oil cake is the best to increase milk fat & solid-not-fat (SNF)	109
C. Feeds and feeding of rural buffaloes				
01	-	Common feeds*	No effect on milk fat	107
D. Benefit of urea feeding in buffaloes				
01.	9 male	70g urea (1% DM)	Increased body weight in buff calves	110
02.	12 heifers	Soaking of straw in urea water (4%)	Feeding urea treated straw increased straw increased body weight gain, feed intake and digestibility	111,116 117
03.	Buffalo calves	Different level of Urea + 1-4C-acetate	Effect on rumen metabolism	118
04.	12 calves	Soaked straw + Fish meal or fish meal + Broken rice mixture	Increased digestibility and body weight gain of buffalo calves	112
05.	12 buffaloes	Urea ensilage & urea soaked straw	Higher body weight gain in both the urea treated feeds	113
06.	12 heifers	Urea treated, Urea + molasses and ensilage straw	No deleterious effects on blood protein, urea, glucose and transaminase levels	114
07.	6+6 lactating	Effect of conc. feeding @ 1g/day/animal on milk composition & yield also increased.	Higher milk yield in concentrate feeding (2.95L)than non-concentrate feeding (1.58L).	115
08.	Cattle = 8 Buffaloes = 4	Comparison of feed utilization between buffalo & cattle	Dry matter (DM), organic matter (OM), nitrogen digestibility & body weight were higher in buffalo than cattle	29
E. Comparison of digestibility between cattle and buffaloes				
01.	Nili-Ravi	Digestibility capacity of buffalo is superior than cattle Rumen microflora may be more efficient in buffaloes		28
02.	Buffalo = 3 Cattle = 3	Green grass =4kg Rice straw = 5kg Conc. = 0.5 kg UMB = 0.5 kg	Growth performance of buffaloes is better than cattle by feeding UMB with straw based diet.	30

UMB= Urea molasses block (molasses 39.0%, wheat bran 20.0%, rice polish 20.0%, urea 10.0% lime (CaO) 6.0% and common salt 5.05). *Roughages 51.7%, Cultivated fodder 21.7%, Tree leaves26.7% and no concentrate supply

deleterious effects on the blood parameters including protein status in buffaloes.[114] The indigenous lactating buffaloes produced higher milk yield with concentrate supplement @ 1g /

day / animal (2.95 liter / day) in comparison to un-supplemented buffaloes (1.58 liter / day). The average protein, ash, solid not fat (SNF) and total solids (TS) have been reported to be higher in concentrate supplemented group than un-supplemented group of buffaloes.[115] Supply of balanced feed remains a challenge in buffalo husbandry due to limited feed resources and research findings. Table 13 shows a feeding schedule of lactating buffaloes under semi-intensive system.

Table 13. Feeding and management of lactating buffalo under semi-intensive system[119]

S/ N	Management	Range (Mean ± SD)	S/ N	Feeding (DM kg^{1} day^{-1} $head^{-1}$)	(%)	Farmers Range (Mean ± SD)
1.	Grazing (hrs./day)	2-80 (6.04 ± 1.52	1.	Straw	89	4.50-16.00 (10.90 ± 2.85)
2.	Confinement (hrs/d)	3-10 (5.91 ± 1.70)	2.	Green grass	100	1.60-11.30 (04.98 ± 2.89)
3.	Wallowing (hrs/day)	1-60 (2.78 ± 1.34)	3.	Concentrate*	57	0.44-02.64 (01.51 ± 0.80)
				Total		6.40-20.30 (16.1 6 ± 3.28)

*Oil cakes, wheat bran, rice bran (0.2kg), soybean meal (0.56 kg) and broken maize (0.75 kg) @ kg/day

Table 14. Feeding trial obtained best results in milk production in buffaloes

SN	Ingredients	Traeted[109]	Treated[115]	Treated [120]	Control[120]
01.	Grazing (hrs)	-	7-8	7-8	7-8
02.	Rice straw +	-	ad libitum	ad libitum	ad libitum
03.	Tree leaves	-	+	-	-
04.	Concentrate (kg/d)	-	1.0[a]	1.0[b]	-
05.	Groundnut oil cake	35	-	-	-
06.	Wheat bran	39	-	-	-
07.	Crushed khesari	24	-	-	-
08.	Steamed bone meal	1	-	-	-
09.	Common salt	1	-	-	-
Milk yield & composition					
01.	Av daily milk yield (L/d)	-	2.95	2.96 ± 0.61	2.58 ± 0.32
02.	Lactation period (days)	-	258.67	264.67 ± 36.06	258.67 ± 69.0
03.	Total yield / lactation (L)	-	762.33	762.33 ± 223.46	683.04 ± 219.85
04.	Milk fat (g/kg)	7.45	-	71.70 ± 6.69	64.40 ± 0.16
05.	SNF (g/kg)	16.32	-	102.5 ± 1.74**	98.80 ± 1.00
06.	Protein (g/kg)	-	-	47.70 ± 0.88**	44.50 ± 0.88
07.	Lactose (g/kg)	-	-	46.30 ± 0.73	46.10 ± 0.90
08.	Ash (g/kg)	-	-	08.40 ± 0.14*	08.20 ± 0.16
09.	Total solids (g/kg)	-	-	174.20 ± 7.89*	164.90 ± 5.64
10.	Water (g/kg)	-	-	825.80 ± 7.83	834.09 ± 0.16*
11.	Acidity %	-	-	0.14 ± 0.01	0.13 ± 0.01
12.	LWG (lbs)	+0.68	-	-	-

[a]Consisted of Rice polish 400g, Matikalai bran 250g, Soybean oil cake 250g and Bone meal 100g
[b]Consisted of rice bran 400g, soybean oil cake 250g, matikalai bran 250g and bone meal 100g

The concentrate feeding @ 1kg / day / animal to lactating buffaloes increased milk yield 2.95 liter in comparison to 2.58 liter in non-concentrate fed cows.[115] Feeding of groundnut oil cake caused increased milk fat 7.45% in comparison to 7.07% in mustard oil cake and 7.09% in Til cake feeding groups of lactating buffaloes.[109] However, the differences of milk yield between the concentrate supplemented and non-supplemented cows did not differ significantly but protein, ash, SNF and total solids of the milk of concentrate supplemented group have been reported significantly higher than non-supplemented control group (Table 14). It was concluded that no concentrate supplementation is required for the indigenous dairy buffaloes in Bangladesh when there is plenty supply of green forage and rice straw.[120]

Table 15 shows the best feed formulations for live weight gain comparison between control and treated groups in buffaloes. The feeding of groundnut cake has been reported to be best in comparison to mustard oil cake and til oil cake in lactating buffaloes,[109] adding of urea up to 1.0% of dry matter has showed useful source of NPN utilization in buffaloes,[110] treatment of straw with urea following either ensiling or soaking in urea-water resulted an increased intake of straw, increased feed digestibility and weight gain in buffalo heifers,[111] supplement of urea soaked straw with fish meal or a mixture of broken rice and fish meal improved the efficiency straw utilization in terms of digestibility and live weight gain in buffalo calves[112] and significantly higher live weight gain have been reported in both the groups of buffaloes fed urea soaked straw and urea ensiled straw.[113] Soaking of straw in urea water may be suggested to village level farmers in Bangladesh as the easily adoptable method of urea incorporation in straw based ration for buffaloes.

Table 15. Feeding trial obtained best results on the increased live weight in young buffaloes

SN Ingredients	Ration A[110]	Ration B[111]	Ration C[111]	Ration D[112]	Ration E[113]	Ration F[114]
01. Paddy straw (kg)	3.6	-	-	-	-	-
02. Urea soaked straw (kg)	-	-	6.96	2.5	-	7.0
03. Urea ensiled straw (kg)	-	7.32	-	-	7.3	-
04. Green grass (kg)	-	1.0	1.0	1.0	1.0	1.0
05. Para grass (kg)	7.2	-	-	-	-	-
06. Wheat bran (kg)	0.9	0.5	0.5	0.3	0.5	0.5
07. Mustard oil cake (kg)	0.4	-	-	-	-	-
08. Fish meal (g)	-	-	-	600	-	-
09. Broken rice (g)	-	-	-	100	-	-
10. Molasses (kg)	1.3	-	-	-	-	-
11. Urea (g)	70	-	-	-	-	-
12. Common salt (g)	50	-	-	-	-	-
Findings						
01. Initial LW (kg)	302.0	159.8	169.8	90.33	159.8	169.8
02. Final LW (kg)	352.2	183.5	192.2	-	183.5	192.3
03. Daily Av LWG (g)	50	296	281	181.13	-	-
04. Net LW gain (kg)	50.2*	23.7	22.4	-	23.7	22.5

- = Data not available in the original articles *Significant at ($p < 0.01$)

Preparation of silage[111,116,117]

- Rice straw was chopped into pieces (5-8 cm length) and spread on concrete floor.
- 4.0% urea solution was prepared by dissolving 40g urea in a litter of water / 1.5 kg fresh straw. Urea solution was sprinkled over the straw with simultaneous mixing.
- Then the whole lot was ensiled by placing them in concrete silo pit.
- The top of the pit was covered with polyethylene sheet on which a thick layer of mud was put.
- The pit was covered with corrugated tin sheet to save it from rain water.
- The silage was opened after 2 weeks and fed to the animals.

Preparation of soaked straw

- Rice straw was chopped into pieces (5-8 cm length) and placed in a concrete chari (big bowl).
- Urea solution was prepared by dissolving 20g of urea in a liter of water for each 1.05 kg of fresh straw.The solution was sprayed on the chopped straw slowly and was mixed thoroughly.
- The straw was left for 2 hours for soaking.
- Two batches of soaked straw was prepared daily and offered to the animals.
- At the time of feeding, there was no liquid effluent left.

Balanced ration of buffaloes

A balanced ration is the amount of feed which provides the right quantity and proportion of nutrients (protein, carbohydrate, minerals, vitamins) from dry fodders, green fodders, concentrates and mineral supplements to enable the animal to perform optimally and remain healthy. Balanced ration is different for different stages of an animal as its requirement is various according to the demands of the body. The maintenance ration is required for every animal that needs for maintenance depending on its type, class and body weight, growth ration is required for better growth with an extra 20% of the maintenance ration depending on age, milk production ration for lactating animals need extra feed above maintenance ration depending on quantity of milk production and its fat percentage, and pregnancy ration especially more than five months of pregnancy requires extra and balance ration. The feed ingredients which are selected for preparing a balanced ration should be nutritive as per standard, palatable, laxative, economical and locally available.

Practical feeding of buffalo calves up to three months of age

Buffalo calves mortality is very high up to three months of age, which is mainly caused by negligence of feeding colostrum, limited milk feeding, injuries and diseases. The care and management of buffalo calf begins 90 days before the calving of the dam because this period of pregnancy involves the optimum growth of the mammary glands and colostrum production with proper quality and volume for the consumption of the newborn. Colostrum is a nutrient-rich first meal for the calf which is high in protein, energy (fat), minerals, vitamins and provides the needed disease preventing antibodies. Colostrum should be fed to calf as soon as possible after birth ideally within one hour.[121] The calf is capable of absorbing the antibodies in the colostrum for only the first 24 hours after birth and the newborn calf has to consume about 10% of its body weight.[121] After colostrum period, whole milk should be provided to the calves until 15 days of age @ $\frac{1}{8}^{th}$ to $\frac{1}{10}^{th}$ of the calf body weight (Table 16). The colostral antibodies

protect the buffalo calves from infectious diseases for six weeks.[122] The high energy value of colostrum allows to prevent possible hypothermia and its high content of magnesium salts has laxative action, helping the calf releasing the meconium and facilitating the intension expulsion.[122]

Milk replacer can be fed along with the whole milk provided that it has a certain composition of nutrients. It is not advisable to completely substitute whole milk with milk replacer. Milk and milk replacer should be offered to the calf on at least two occasions per day at the body temperature (38-39 ^{0}C). At two weeks of age, the calf should be introduced to good quality green grass and concentrates as a calf starter, which stimulates the rumen to grow and function properly.

The calf starter and green grass should be offered to the calf from second[123]/third[124] week of life to speed up development of rumen and early initiation of microbial fermentation (Table 16). As intake of calf starter and green grass increases that reduces the milk gradually as per schedule (Table 16). Calf starter should contain 22% CP and 70-75% TDN and it should be prepared from good quality feeds which should be easily digestible low fiber feed and free from any contamination (Table 17).

Table 16. Daily feeding schedule of buffalo calves from birth up to 3 months of age

Schedule A[124]					**Schedule B**[123,125]			
Age (days)	Whole milk (L)	SM/MR (L)	Calf starter (g)	Green grass (g)	Age (days)	Whole milk (kg)	Calf starter (kg)	Green grass (kg)
00-14	04	-	-	-	01- 07	2.5	0.00	0.00
15-21	3.5	-	50	300	08 -14	2.5	0.05	0.25
22-28	3.0	-	300	500	15 - 21	3.0	0.10	0.35
29-35	1.5	1.0	400	550	22 - 28	3.5	0.20	0.50
36-42	-	2.5	600	600	29 - 35	3.5	0.40	0.55
43-49	-	2.0	700	700	36 - 42	3.0	0.60	0.60
50-56	-	1.5	800	800	43 - 49	3.0	0.70	0.70
57-63	-	1.0	1000	1000	50 - 56	2.0	0.80	0.80
64-70	-	-	1200	1100	57 - 63	1.5	1.00	1.00
71-77	-	-	1300	1200	64 - 70	1.5	1.20	1.10
78-84	-	-	1400	1400	71 - 77	1.0	1.30	1.20
85-91	-	-	1700	1900	78 - 84	0.5	1.40	1.40
					85 - 90	0.0	1.70	1.90

SM/MR = Skim milk / Milk replacer, L = Liter

The rumen is developed substantially in three months old calves and microbial digestion in rumen become functional and suckling is not usually allowed at this phase. Generally, at this stage 10 kg cereal fodder or 15 kg leguminous fodder with straw *ad libitum* and 1.0 kg concentrate are required to feed the growing calf.[125] Generally 12% CP and 58-60% TDN in ration will support 450-550g average daily growth rate in buffalo calves from 6 months of age. Table 18 shows the balanced ration for pregnant and lactating buffaloes.

Table 17. Some calf starter formulae for buffalo calves

SN	Ingredient	Formulae and amount (kg/100 kg or % composition)[123,124,125]									
		1	2	3	4	5	6	7	8	9	10
01	Crushed maize	30	42	38	50	10	-	-	50	49	-
02	Crushed barley / oat	10	-	-	-	10	10	-	-	-	50
03	Crushed ragi/jowar	10	-	-	-	-	-	20	-	-	-
04	Crushed wheat / rice	-	-	-	-	30	40	30	-	-	-
05	GN cake / Soybean meal	30	28	20	40	20	30	30	27	30	30
06	Til cake / Linseed meal	-	-	-	-	-	-	08	10	10	-
07	Mustard cake	-	-	-	-	10	-	-	-	-	-
08	Fish meal	10	08	-	-	-	-	-	-	08	-
09	Wheat bran	07	19	26	07	10	10	10	10	10	08
10	Molasses	-	-	-	-	07	07	-	-	-	5-10
11	Skimmed milk powder	-	-	13	-	-	-	-	-	-	10
12	Mineral mixture	02	02	02	02	02	02	02	02	02	02
13	Common salt	01	01	01	01	01	01	01	01	01	0.5

If green grasses are not fed in that cases supply vitamin (A, B2, D3) @ 10g/ quintal mixture

Table 18. Feeding schedules for pregnant and lactation buffaloes[123,124,125]

Ration for pregnant buffaloes			Ration for lactating buffaloes (450 kg BW)			
SN Pregnancy stage	Ingredients	Amount	Milk yield (kg/day)	Conc. (kg)	Green grass (kg)	Straw (kg)
1. Early stage (<5 M)	Ration	Maintenance	6	2.7	15	8.0
2. Late stage (>5 M)	Green fodder	30 kg	6	5.5	-	6.4
	Concentrate	02 kg	8	3.7	15	8.0
	Straw	*ad libitum*	8	6.4	-	7.5
3. First pregnancy	Concentrate	1kg + extra	10	4.8	20	7.0
(Fetal growth:	Cereal fodder	5.5 kg	10	7.3	-	7.6
300-350g/d)	Legume fodder	7.5 kg	12	5.6	20	8.3
4. Second pregnancy	Concentrate	0.5+ extra	12	8.5	-	8.3
(Fetal growth:	Cereal fodder	2.7 kg+/	14	6.5	20	7.0
120-200g/d)	Legume deer	3.7 kg+ extra	14	9.8	-	8.2
5. Dry period	Green fodder	20-25 kg	7-8	3.5-4.0	25-30	4-5
	Straw	5-6 kg	16	7.0	20	7.0
	Concentrate	0.5-1.0 kg	16	10.9	-	9.3

Benefits of the balanced rations for cattle and buffalo production include: (a) Efficient utilization of locally available feed resources, (b) Improvement of milk production and quality (SNF & fat), (c) Possible reduction in dairy feeding cost, (d) Increase in net daily income, (e) Improvement in reproduction efficiency of animals, (e) Reduction in calving interval and as a result increase productive life, (f) Improvement in the growth rate of calves leading to early maturity and earlier calving, (g) Reduction in parasitic load, (h) Better immune response, hence

better resistance against diseases, (i) Reduction in methane emission and Reduction in nitrogen excretion.[126] The concept of balanced ration is already in practice in most of the developed countries in their dairy industries where feed resources are available in abundance and reared their animals mostly in herds. However, inadequate and imbalance feeding practice are the major factors responsible for low productivity in animals in most of the developing countries including Bangladesh. Therefore, the chemical composition and nutritive values of locally available feed resources including agriculture by-products and allied industries should be analyzed for the formulation balanced ration for livestock. Accordingly, the balanced ration for each species of livestock with different productive and reproductive stages should be prepared based on research trial studies with locally available feed stuffs. Then it is possible to advice to the farmers to use the package of balanced ration formulae to feed their animals. In addition to formulae of balanced ration, dairy farmers also need to be educated through an efficient extension service about the importance of drinking water, proper feeding mangers, colostrum feeding to newly born calves, suitable chaffing of fodder, de-worming, vaccination, timely insemination and others.

Pre-clinical research on buffaloes

The pre-clinical studies basically comprise of anatomy, histology, biochemistry, physiology, microbiology, parasitology, pharmacology, toxicology and pathology. An attempt has been made to compile research findings on pre-clinical and clinical aspects on buffaloes.

Anatomy, histology, biochemistry and physiological research

Buffalo anatomy which means the study of structure and relationship between body parts of buffaloes and buffalo physiology is the study of function of body parts and the body as a whole of buffaloes. Biochemical profile (biochemistry) is essential in the evaluation of the health status and a prerequisite for the diagnosis of various pathophysiological, metabolic and nutritional disorders in both animals and humans. The biochemical values cannot remain standard forever due to different factors especially nutrition, physiology of production and reproduction, diseases and therefore needs to re-examine from time to time to detect the pathophysiological conditions. Table 20 shows the major research findings on anatomy, histology, physiology and biochemistry in buffaloes published from Bangladesh.

It appears from Table 20 that the anatomy and histological research on buffaloes has started since 1971 from the then East Pakistan[127,128] and so far only 15 research reports on buffalo anatomy and histology are recorded in available literatures. However, the physiological research reports have been published for the first time in 1968 and up-to-date review reveals that only eight research reports have been published since 1968 in Bangladesh (Table 20).

Bacteriological research in buffaloes

Buffaloes have always suffered from a wide range of bacterial diseases. For the diagnosis and treatment, it is essential to isolate and identify the causative bacterial pathogens from the affected animals and to perform the antibiogram studies to select the highly effective antibacterial drugs for the treatment of the clinical cases. Moreover, bacterial isolation, purification and identification are the first step to bacteriological studies. The inland reports on

Table 20. Major findings of the anatomy, histology, physiology and biochemistry research in buffaloes

SN	Research aspect	No. of buffaloes	Main findings	Ref. Nos.
A. Anatomy and histological research				
01.	Os cordis	21	Length (6 cm), breath (1 cm) & thickness (0.4 cm)	127
02.	Stomach	-	Preparation of natural model of stomach	128
03.	Nerve supply	20	Horn and horn base derived from corneal nerve	129
04.	Muzzle gland	-	Histology of muzzle gland	130
05.	Urethra & Sub-urethra	16	Length and width of urethra (6-8 cm) & SUD (2/3cm)	131
06.	Mammary gland	-	Innervation status	132
07.	Histology of skin	06	The average skin thickness was 5.53 mm	133
08.	Coronary arterial anatomy	16	The right coronary artery was smaller than left	134
09.	Histology of sweat glands	06	Study the skin sweat glands	135
10.	Microscopic properties	275	The average thickness of the skin was 4.9 ± 1.3 mm	136
11.	Kidneys	-	External lobulation with 25-33 lobes in buffaloes	137
12.	Mammary gland	05	The course of artery supply of the mammary gland	138
13.	Arterial supply of spleen	-	Receives three splenic arteries	139
14.	Appendicular skeleton	15	Compared with ox skeleton	140
01.	Spleen microscopy	05	The capsule was loosely covered by a serous membrane	141
C. Biochemistry & Physiological research				
01.	Rectal temperature		Normal body temperature	142
02.	Hematology		Normal blood values	143
03.	Pulse and respiration		Normal pulse & respiratory rates	144
04.	Specific gravity of blood fluids		Normal whole blood, serum & plasma	145
05.	Breeding season	900 (‘67-‘70)	During Octo-Jan 66% buffaloes came to heat	146
06.	Biochemical values	15+15	Murrah & Manipuri breeds	147
07.	Estrus period	15	Changes in behavior & external genitalia	148
08.	ESR	-	Higher ESR in Manipuri than Murrah	149

*Murrah & Manipuri breeds (1-8 years age) - = Data not available

bacteriological research on buffaloes are reviewed and analyzed in Table 21. Review of available literature reveals that no bacteriological research reports have been published during the East Pakistan period (Table 21). So far only seven research reports on bacterial infections in buffaloes have been published from Bangladesh (Table 21). Only two bacteria (*Staphylococcus* spp. and *Pasteurella haemolytica*) have been isolated and identified from trachea and lung samples of slaughtered buffaloes (Table 21).[150,151] Two reports on bacteriological isolation and identification on diarrheic fecal samples have been reported with *E. coli* and *Salmonella* spp. infections. (Table 21).[152,153] Bacteriological examination of milk samples detected coagulase -ve Staphylococci (CNSs), *Streptococcus* spp., *Bacillus* spp., *Staphylococcus aureus* and *E. coli* infections (Table 21).[153,154] *Salmonella* spp. have been isolated and identified as a carrier state in rectal swabs in buffaloes.[155,156] It appears that the respiratory system, digestive system and udder infections are more commonly encountered in buffaloes in Bangladesh.

Antibiogram studies

The main objectives of antibiotic sensitivity testing are to detect possible drug resistance in common pathogens and to assure susceptibility to drugs of choice for treatment and control of

Table 21. Bacteriological research on isolation and identification of bacteria with their antibiogram

S/N	District	Duration of research	No. of cases	Organ's samples	Bacteria isolated & identified	Total (%)	Ref. No.
01.	Barisal	2006-2007	80	Trachea	*Staphylococcus* sp.	04 (05.00)	150*
			80	Lungs	*Staphylococcus* sp.	13 (16.25)	
					Pasteurella haemolytica	04 (05.00)	
02.	Dinajpur	2011-2012	80	Trachea	*Staphylococcus* spp.	04(5.00)	151*
			80	Lung	*Staphylococcus* spp.	13(16.25)	
					Pasteurella haemolyticum	04 (05.00)	
03.	3 districts!	2008-2009	50	Diarrheic feces	*Escherichia coli*	23 (46.05)	152
04.	Dhaka	2012-2014	72	Diarrheic feces	*E. coli*	45 (62.50)	153
					Salmonella spp.	21 (29.16)	
			114	Milk	Bacteria isolated**	+	153
05.	BAUDF	-	03	Milk	*Staph. aureus*	1+	154
					E. coli	1+	
06.	Mymensingh-		38	Rectal swabs	*Salmonella* spp.	08 (20.63)	155
07.	Dhaka & SG-		64	Rectal swabs	*Salmonella* sp.	01 (01.60)	156

3 districts! = Tangail, Mymensingh and Sirajgonj (SG) *Appears plagiarism
+ = Data are shown only in figure
** Coagulase-ve Staphylococci, *Streptococcus* spp., *Bacillus* spp. and *Staphylococcus aureus*

particular bacterial infection. Available reports suggest that the antibiotic resistance has reached unacceptable levels in the bacterial pathogens associated with diseases in both animals and humans and that trends show further increases in developing countries like Bangladesh.

Out of 50 fecal samples tested bacteriologically, of which 23 (45.0%) were found positive for *E. coli* infection in buffalo calves (Table 21). The antibiogram study showed that the isolated *E. coli* was highly sensitive to enrofloxacin and ciprofloxacin, moderately sensitive to cephalexin and amoxicillin and resistant to nalidixic acid and erythromycin (Table 22).[152]

All isolates of salmonella species were positive to 16s rRNA gene based PCR (574bp). All these Salmonella isolates were susceptible to ciprofloxacin, streptomycin and gentamicin but resistant to amoxicillin, and some isolates to erythromycin, tetracycline, azithromycin and cephradine.[155,156]

Milk samples of three buffaloes were examined by bacteriological and PCR, of which one sample has reported to be positive for *E. coli* and *S. aureus*.[154] Mastitis caused by E. coli and *S. aureus* can be effectively treated with the sensitive to ciprofloxacin and levofloxacin in large ruminants.[154]

The occurrence of Shiga toxin-producing E. coli (STEC) has been reported in apparently healthy smallholding buffaloes in Chittagong district of Bangladesh. Of the 100 fecal samples screened bacteriologically, of which 71 found positive for *E. coli* infection. The proportion of

Table 22. Antibiogram status of bacteria isolated from buffaloes in Bangladesh

SNAnti-bacterials	*Escherichia coli*[152]				*P. multocida*[157]		*Salmonella* spp.[155]		
	R	LR	MS	HS	R	S	HS	MS	LS
01. Ciprofloxacin	0	28.17	45.0	26.83	-	-	HS	-	-
02. Enrofloxacin	12.17	43.49	21.17	23.17	-	-	-	-	-
03. Amoxicillin	22.51	51.22	26.17	0	-	-	-	-	-
04. Gentamicin	0	33.33	66.67	0	-	-	-	MS	-
05. Erythromycin	33.33	66.67	0	0	-	-	-	-	LS
06. Cephalexin	0	66.67	33.33	0	-	-	-	-	-
07. Cloxacillin	4	0	0	0	-	-	-	-	-
08. Nalidixix acid	36.67	33.33	0	0	-	-	-	-	-
09. Chloramphenicol	-	-	-	-	0	100	-	-	-
10. Ampicillin	-	-	-	-	0	100	-	-	-
11. Sulfadimidine	-	-	-	-	100	0	-	-	-
12. Tetracycline	-	-	-	-	100	0	-	MS	-
13. Streptomycin	-	-	-	-	100	0	-	-	-
14. Neomycin	-	-	-	-	100	0	-	-	-
15. Furazolidone	R	-	-	-	100	0	-	-	-
16. Co-trimoxazole	-	-	-	-	100	0	-	MS	-

R = Resistance LR = Less resistance S = Sensitive LS = Less sensitive
MS = Moderate sensitive HS = Highly sensitive
*No. of isolates used for antibiogram test not mentioned

buffaloes harboring STEC isolates was 11 (11%), of which 7% and 4% carried stx1 and stx2 genes, respectively. Of the 11 STEC isolates, 91% (10/11), 73% (8/11), 55% (6/11) and 55% (6/11) were resistant to tetracycline, sulfamethoxazole-trimethoprim, erythromycin and ampicillin respectively, whereas 91% (10/11) isolates were sensitive to ciprofloxacin, chloramphenicol and gentamicin.[158] It appears that the transmission of anti-microbial resistant STEC from buffaloes to humans could pose an added risk to public health in rural Bangladesh.

Bacteria isolated from buffalo carcasses and meat

Most of the bacteria contaminate the carcasses and meat is non-pathogenic but some are highly pathogenic which includes Staphylococcus spp., Salmonella spp., Escherichia coli 0157:H7, Campylobacter spp. and Listeria monocytogens that poses a safety challenge to the meat industry worldwide especially developing countries like Bangladesh. Review of available literature reveals only one report on bacterial contamination of buffalo meat could be traced from Bangladesh (Table 23).[159]

The bacterial load in buffalo meat exceeded the ICMSF (International Commission on Microbiological Specification for Foods) recommendations values (Table 23). Detection of high bacterial load in buffalo meat especially pathogenic Salmonella spp. indicates that the meat sold in slaughterhouses and retail shop may endanger consumer health in Bangladesh.

Table 23. Range (Mean) values of bacterial load in meat samples of 30 buffaloes

SN	Districts	TVC	TSaC	TSC	Salmonella spp.	Ref. No.
1.	Mymensingh	7.42-8.80 (8.13)	4.98-6.99 (6.01)	4.03-5.74 (4.71)	3.0-6.0 (4.66)	159

TVC = Total viable count TSaC = Total Staphylococcal count TSC = Total Salmonella count

Although these Salmonella spp. are sensitive to ciprofloxacin, gentamicin and streptomycin, they are resistance to amoxicillin (100%), erythromycin (85.71%), tetracycline (50.00%) and 28.57% to azithromycin.[159]

Parasitological research on buffaloes

Parasites are one of the major causes of economic losses to the buffalo production associated with sub-clinical and clinical parasitism with high morbidity and mortality rates in buffalo calves. The research findings on buffalo parasites published in different journals from Bangladesh are reviewed and analyzed (Table 24).

Table 24. Major findings on the occurrence of buffalo parasites in Bangladesh

SN	District Nos.	Species of parasites	No. of buffaloes	Prevalence No. (%)	References Nos.
A. Ectoparasites					
01.	1-5 (Lice)	*Haematopinus tuberculatus*	886	349 (39.39)	160,161,162
02.	1-5 (Ticks)	*Boophilus microplus*	236	033 (13.98)	160
03.	1,2,4,5 (Ticks)	*Haemaphysalis bispinosa*	716	066 (09.22)	160,161
B. Endo-parasites (Overall prevalence)					
O1.	3,6	Gastro-intestinal parasites	506	251 (49.60)	163,164
02.	4	6 species of parasites[1]	178	126 (70.8%)	165
03.	1-5	5-types of parasites[2]	480 Live 180 viscera	- -	161
II. Trematodes					
01.	1-9,11,13	Paramphistomes (*Paramphistomum cervi*)	4125	2564 (62.16)	153,161,163, 166-168
02.	4,6,10	Amphistomes	1576	816 (51.76)	164,169-171
03.	1-8,11,13	*Fasciola gigantica*	6600	3073 (46.56)	153,161,163,164, 166-168, 170-173
04.	6	Fasciola + Amphistomes	270	25 (09.26)	164
05.	Schistosomes				
a.	4,11	*Schistosoma* spp.	3807	364 (09.56)	166,168,171
b.	1-5,12 ,13	*S. indicum*	1375	43 (03.13)	153,161,163,167
c.	1-5,13	*S. spindale*	1213	81 (06.68)	161,163,167
d.	6	*S. bovis*	270	03 (01.11)	164
e.	1-5	*S. nasalis*	480	22 (04.58)	161

III.Nematodes				
01. 3,12,13	Strongyles	3615	894 (24.73)	153,163,166,167
02. 1-6, 12,13	*Toxocara vitulorum*	6273	844 (13.45)	153,161,163,164,166, 167, 170,174
03. 4	*T. vitulorum* larvae in milk	12	Larva migran	175,176
04. 4,13	*Trichuris* spp. (*T. ovis*)	4274	404 (09.80)	166,167,171
05. 1-5,12,13	*Strongyloides papillosus*	2432	576 (24.10)	153,161,163,167,171
06. 1,2,4-6,	*Trichostrongylus axei*	1807	244 (13.50)	161,164,171
07. 4,10,13	*Haemonchus contortus*	1767	320 (18.11)	167,170,171
08. 1,2,4,5,13	*Capillaria bovis*, *C. bilobata*	977	43 (04.40)	161,167
09. 1,2,4.5	*Thelazia rhodesii*	480	11 (02.29)	161
10. 1,2,4,5	*Osophagostomum radiatum*	480	32 (06.67)	161
11. 1,2,45	Hookworm (*Bunostomum* sp.)	1537	217 (14.12)	161,171
12. 1,2,4,5	*Mecistocirrus* spp.	1537	257 (16.72)	161,171
13. 4	*Ostertagia* spp.	1057	170 (16.08)	171
14. 4	*Cooperia* spp.	1057	131 (12.39)	171
IV. Cestodes				
01. 4	*Moniezia* spp. (*M. expansa*)	1554	16 (01.03)	167,171
V. Protozoa				
01. 3,10,12	*Balantidium coli*	3331	1423 (42.72)	153,163,166,170
00. 13	*Buxtonella sulcata*	497	186 (37.40)	167
02. 1-5,12,13	*Eimeria* spp. (*E. zuerni*)	4095	981 (23.96)	153,161,163,166,167
03. 1,2,4,5	*Trypanosoma theileri*	480	02 (0.42)	161

[1]Six species of parasites = *Neoascaris vitulorum*, *Strongyloides papillosus*, *Strongylus* sp., *Trichuris* spp., *Bunostomum* sp. and *Cooperia* sp.[164] [2]Five-types of parasites = Trematodes (n = 8) , Cestodes (n = 2), Nematodes (n = 14), Protozoa (n = 2), Arthropods (n = 2)

1 = Bogra 2 = Dhaka 3 = Kurigram 4 = Mymensingh 5 = Rajshahi 6 = Barishal 7 = Chittagong 8 = Sylhet 9 = Rangpur 10 = Bagerhat 11 = Saint Martin's Island 12 = Coastal districts 13 = Bhola

Parasites are of two major groups, endoparasites and ectoparasites. The endoparasites are classified into trematodes, nematodes, cestodes and protozoa (Table 24). Table 24 shows that a total of 25 species of endoparasites have been reported in buffaloes from Bangladesh, of which six species are trematodes (Paramphistomum cervi 62.16%, F. gigantica 46.56%, Schistosoma indicum 3.13% and S. spindale 6.68%, S. bovis 01.11%, S. nasalis 04.58%), 14 species of nematodes (Strongyles 24.73%, Toxocara vitulorum 13.45%, Trichuris ovis 9.80%, *Strongyloides papillosus* 24.10%, *Trichostrongylus axei* 13.50%, *Haemonchus contortus* 18.11%, *Capillaria bovis*, *C. bilobata* 4.40%, *Thelazia rhodesii* 2.29%, *Osophagostomum radiatum* 06.67%, *Bunostomum* sp. 14.12%, *Mecistocirrus* spp. 16.72%, *Ostertagia* spp. 16.080% and *Cooperia* spp. 12.39%, one species of cestode (*Moniezia expansa* 1.03%) and four species of protozoa (*Balantidium coli* 42.72%, *Buxtonella sulcata* 37.40%, *Eimeria* spp. (*E. zuerni*) 23.96 and *Trypanosoma theileri* 0.42%).

The *Paramphistomum cervi* (62.16%), amphistomes (51.76%) and *Fasciola gigantica* (46.56%), *Balantidium coli* (42.72%), *Eimeria zuerni* (23.96%) and *Toxocara vitulorum* (13.45%) infections are widely prevalence in buffaloes in Bangladesh. Parasites cause different types of

harmful effects in livestock including buffaloes.[177] External parasites cause irritation, un-thriftiness, hair loss, interferes with rest of buffaloes, blood sucking cause anemia, vector to transmit diseases and produce toxic substances which cause allergic reactions. The endoparasites damage gastro-intestinal tissues, interfere with normal digestion and absorption of nutrients result in diarrhea, malabsorption, emaciation, anorexia, weight loss, low grade fever and depressed growth. Overall parasitic infestation causes both sub-clinical and clinical infections associated with decrease growth rate in calves and reduce production and reproduction in adult buffaloes. Early diagnosis through isolation and identification of parasites are the keys to successful treatment and control of the parasites in buffaloes. The fecal samples should be regularly examined microscopically for detection of eggs of parasites for the early treatment of animals.

Pathological research findings in buffaloes

Anatomic pathologists perform autopsies (organs, tissues & bodies) and collect blood and tissue samples to determine the possible cause (laboratory analysis) of a disease. The buffalo diseases reported based on pathological diagnosis from Bangladesh are presented in Table 25.

Table 25. Main research findings on pathological investigation of dead buffaloes in Bangladesh

SNParasites	Districts	No. of buffaloes	Prevalence No. (%)	References Nos.
A. Systemic pathological disorders				
01. Cachexia	Mymensingh	173	006 (03.47)	178
02. Liver cirrhosis	Dhaka, Barishal	518	113 (21.81)	179,180
03. Liver abscess	Dhaka, Barishal	518	005 (00.97)	179,180
04. SCAF (liver)	Dhaka	438	022 (05.02)	179
05. Rupture (liver)	Dhaka	438	006 (01.37)	179
06. Haemorrhage (liver)	Dhaka, Barishal	518	028 (05.41)	179,180
07. Telangiectasis (liver)	Dhaka	438	003 (00.68)	179
08. Nodular hepatitis	Barishal	080	006 (07.50)	180
09. Granulomatous hepatitis	Barisahl	080	004 (05.00)	180
10. Cholecystitis (parasitic)	Barishal	080	012 (15.00)	180
11. Pathology of trachea & lungs	Barishal	080	012 (15.00)	181
B. Parasitic pahology				
I. Trematodes				
1. Fascioliasis	DMBR	1189	518 (43.57)	161,172,178-180,182
2. Paramphistomiasis	DMBR	353	101 (28.61)	161,178
a. *Ceylonocotyl scoliocelium*	BAUDF		5 (PM)	183
3. Amphistomiasis (immature)	DMBR	1028	645 (62.74)*	161,172,173,179, 180, 182-184
4. Fasciola + Gigantocotyle	-	212	76 (35.85)	172,182
5. Schistosomiasis: *S. indicum*	DMBR	180	57 (31.63)	161
S. spindale			50 (27.78)	
S. nasalis			15 (08.33)	

II. Nematodes				
1. *Strongyloides papillosus*	DMBR	180	39 (21.67)	161
2. *Capillaria bovis, C. bilobata*	DMBR	180	36 (20.00)	161
3. *Oesophagostomum radiatum*	DMBR	180	36 (20.00)	161
4. Hook worm	DMBR	180	31 (17.22)	161
5. *Trichostrongylus axei*	DMBR	180	39 (21.67)	161
6. Haemonchus / *Mecistocirrus* sp.	DMBR	180	46 (25.56)	161
7. *Toxocara vitulorum*	DMBR	180	46 (25.56)	161
8. *Setaria digitalis*	DMBR	180	13 (07.22)	161
9. *Onchocera armillata*	DMBR	180	49 (27.22)	161
III. Cestodes				
1. *Echinococcus granulosus*	DMBR	3883	1509 (38.86)	161,178,179,180, 184-188
2. *Cysticercus tenuicollis*	DMBR	180	20 (11.11)	161

DMBR = Dhaka, Mymensingh, Bogra and Rajshahi
*Death caused by immature Ceylonocotyle scoliocoelium was associated with duodenitis and severe hepatic damage, Gigantocotyle explanatum infection and Gongylonema pulchrum

Diseases and disorders in buffaloes

Some general constraints on buffalo production in Bangladesh have been reported[189] but diseases and disorders are thought to be the major constraints that hinder the development of buffaloes in Bangladesh (Table 26). Buffalo diseases are caused by multiple etiological agents and risk factors associated with heavy economic loss to the buffalo industry in the form of morbidity and mortality, lowered general health condition, retarded growth, lower work output, decreased milk and meat production.[153] The water buffalo is susceptible mostly by the same diseases and parasites of cattle with some varying susceptibility. The effects of diseases on the buffalo and its productivity are comparatively less than cattle.[190] Buffaloes are comparatively less affected with ticks but highly susceptible to specific lice (*Haematopinus tuberculatus*).[160] Buffaloes are more susceptible 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.[20,190]

Clinical findings of most common buffalo diseases are very similar to cattle but buffaloes are comparatively less susceptible to most of these diseases than cattle. The disease resistance characteristic favors the buffalo to survive in hot humid regions but buffalo calves are highly susceptible to diseases than adult buffaloes. Therefore, diseases have been recognized to be associated with high rates of morbidity and mortality in buffalo calves. Calf pneumonia and diarrhea resulting from management, environmental, nutritional, and physiological variations and various infectious and parasitic agents are the most important causes of buffalo calf mortality.[191] Table 27 shows the reproductive disorders of slaughter buffaloes. Table 28 shows the bacteria isolated and identified from the genital tract of buffaloes.

Table 26. Main research findings on diseases and disorders in buffaloes in Bangladesh

SN	Diseases and disorder	Districts	No. of buffaloes	Prevalence No. (%)	References Nos.
A. Systemic disorders in buffaloes					
01.	Bloat / Tympany	Mymensingh	755	31 (04.11)	192-194
02.	Impaction	Mymensingh	698	04 (00.57)	192,193
03.	Debility	Mymensingh	379	06 (01.58)	192
04.	Pneumonia	Mymensingh	698	12 (01.72)	192,193
05.	Pyrexia/ Fever	Mymensingh	755	62 (08.21)	192-194
06.	Gastro-enteritis/ diarrhea	Mymensingh	1391	28 (02.01)	192,193,195
07.	Bottle -jaw	Mymensingh	319	03 (00.94)	193
08.	Pica (soil eating)	Mymensingh	319	12 (03.76)	193
09.	Inappetence	Mymensingh	319	117 (36.68)	193
10.	Indigestion	Mymensingh	319	03 (00.94)	193
B. Skin diseases & disorders					
0.	Overall	-	326	39 (12.0)	196
1.	Physical dermatosis	-	-	-	197
2.	Psoroptosis	-	652	30 (04.60)	196
3.	Cutaneous papillomatosis	-	326	4 (1.23)	196
4.	Subcutaneous abscess	-	326	5 (1.53)	196
5.	Cutaneous nodules	-	326	13 (03.99)	196
6.	Aurual stephanofilariasis	-	326	7 (2.14)	196
7.	Ulcerative dermatosis	-	319	02 (00.63)	193
8.	Dermatophytosis	Mymensingh	01	Teeburb (Herbal)	198
C. Parasitic diseases of buffaloes					
0.	Overall (GIT parasites)	CSRBSM	462	216 (46.75)	164,167,168
1.	Helminthiosis	-	379	150 ()	192
2.	Coccidiosis	-	379	15 (39.58)	192
3.	Ecto-parasitosis	Mymensingh, Kurigram	934	169 (18.09)	160,192,193
4.	Lice infestation	-	693	56 (08.08)	195
5.	Otorrhoea	Mymensingh	319	02 (00.63)	193
6.	Aurual stephanofilariasis	-	326	7 (2.15)	196
7.	Fascioliasis	Mymensingh, St Martin	11250	150 (1.33)	40,194,195
8.	Paramphistomiasis	Mymensingh	69	34* (39.13)	183,194
9.	Toxoascariasis	Mymensingh	57	08 (14.04)	194
	Route of infection		-	-	199
	Anthelmintic efficacy		-	-	177,200
	Migration of larvae in lab animals		-	-	201
	Pattern and control		-	-	202
10.	Linguatulosis	-	1	1	203
11.	Humpsore	Mymensingh	319	01	193
12.	Balantidiasis	Mymensingh, Tangail	1401	133 (08.07)	204,205

CSRBSM = Chittagiong, Sylhet, Rajshahi, Barishal & St Martin *Out of 34 buffaloes, 5 died

SN Diseases & disorder	Districts	No. of buffaloes	Prevalence No. (%)	References Nos.
D. Bacterial diseases				
01. Bacterial diarrhea	Coastal districts	72 *E. coli*	45 (62.50)	153
		Sal. sp.	21 (29.16)	
		UI	06 (08.33)	
02. Anthrax	64 districts	150297	290 (00.19)	206
		Death	06 (2.18)	
	Bagherhat	60	10 (16.7)	106
	St Martin Island	-	-	40
03. Haemorrhagic	Mymensingh &	150,676	1640 (1.09)	206
septicemia (HS)	64 districts	Death	155 (9.92)	
Sick/dead buffaloes	Mymensingh	-	20 (5.3%)	192
Outbreak of HS	Bhola & Lakshmipur	-	-	157
	Bagherhat,	60	5 (8.3%)	106
	St. Martin	-		40
	Rajshahi, Mymensingh	1+1	Type B	207
04. Bovine tuberculosis	BLRI, Savar: CFT	49	03 (6.25)	208
05. Actinomycosis	-	379	02 (00.53)	192
06. Black leg	Mymensingh, Bagerhat	439	12 (02.73)	107,192
07. Mastitis				
a. Clinical mastitis	Mymensingh, Coastal	1126	57 (05.06)	153,193,195
b. Sub-clinical mastitis	Coastal districts, Barisal, Bagherhat	698	210 (30.09)	153,209,222 223
08. Brucellosis (iELISA)	Bagerhat, Mymensingh	70	03 (4.29)	210,211
E. Viral diseases				
01. Foot-and-Mouth	Bagherhat, St. Martin,	150676	8875 (05.89)	40,106,192
disease (FMD)	64 districts	Death	68 (0.77)	206
02. Rabies / Dog bite	Mymensingh	141128	141 (00.10)	192,193,195
	64 districts	Death	20 (15.50)	206
03. Warts	-	326	04 (1.23)	196
04. Virus diarrhea (outbreak)	Mymensingh	21	21	212
F. Clinical reproductive disorders				
01. Infertility	Mymensingh	379	45 (11.87)	192
02. Abortion	Mymensingh	379	12 (03.17)	192
03. Dystocia	Mymensingh	379	07 (01.85)	192
04. Stillbirth	Mymensingh	379	02 (00.53)	192
05. Retained placenta	Mymensingh	698	16 (02.29)	192,193
06. Post-partum hemorrhage	Mymensingh	379	02 (0.53)	192
07. Uterine prolapse	Mymensingh	379	05 (01.32)	192
08. Lactation failure	Mymensingh	319	03 (00.94)	193
09. Repeat breeding	Mymensingh	319	01 (00.31)	193
10. Pregnancy diagnosis	Mymensingh	319	07 (02.19)	193

Sa = Salmonella UI = Unidentified

Table 27. Prevalence of reproductive disorders based on slaughter buffaloes[213,214]

SN Disorders	No. of buffaloes	Prevalence No. (%)	SN Disorders	No. of buffaloes	Prevalence No. (%)
01. Anestrus	601	122 (20.30)	02. Cystic ovary	851	92 (10.81)
03. Vaginitis	601	69 (11.48)	04. Metritis	601	58 (09.65)
05. Cervicitis	601	56 (09.32)	06. Retained placenta	601	42 (06.99)
07. Dystocia	601	41 (06.82)	08. Abortion	601	40 (06.66)
09. Pyometra	851	65 (07.64)	10. Stillbirth	601	33 (05.49)
11. Uterine prolapse	601	20 (03.33)	12. Pre-mature birth	601	10 (01.66)
13. Endometritis	250	37 (14.80)	14. PCL	250	17 (06.80)
15. Parovarian cysts	250	14 (05.60)	16. Ovary-bursal adhesion	250	13 (05.20)
17. Muco-metra	250	09 (03.60)	18. Salpingitis	250	08 (03.20)
19. Uterine cysts	250	07 (02.80)	20. Oophoritis	250	06 (02.40)
21. Cyst in fallopian tube	250	05 (02.00)	22. Non-functional ovary	250	03 (01.20)
23. Cyastic corpora nigra	250	02 (00.80)	24. Hydrometra	250	02 (00.80)

PCL = Persistent corpus leuteum

Table 28. Bacteria isolated and identified from genital tract of slaughtered buffaloes[215]

SN Bacterial species	No. of buffaloes	Prevalence No. (%)	SN Bacterial species	No. of buffaloes	Prevalence No. (%)
1. *Staphylococcus aureus*	90	43 (47.78)	2. *Streptococcus pyogenes*	90	22 (24.44)
3. *Escherichia coli*	90	08 (08.89)	4. *Bacillus* spp.	90	02 (02.22)
5. *Proteus* spp.	90	12 (13.33)	6. *Klebsiella* spp.	90	04 (04.44)

Therapeutic trials in anestrus buffaloes

Research reports on therapeutic efficacy of differnet drugs in reproductive disorders in buffaloes in Bangladesh are very limited (Table 29). The Dinoprost ($PGF_2\alpha$) has been used to

Table 29. Summary of results on therapeutic trials in anestrus buffalo cows

SN Districts	Treated with	No. of cows	Estrus No. (%)	Conception No. (%)	Ref. No.
1. Bhola, Patuakhali	Anthelmintic + Vitamin	15	03 (20.0)	01 (33.33)	83
	$PGF_2\alpha$	15	05 (33.3)	01 (20.00)	
	GnRH	15	06 (40.0)	02 (33.33)	
	GnRH & $PGF_2\alpha$	15	10 (66.7)	05 (50.00)	
2. Mymensingh & Jessore	Prajana	20	15 (75.0)	11 (73.33)	216
	Banjhana	15	12 (80.0)	09 (75.00)	
	Control	10	01 (10.0)	0	
3. Mymensingh	$PGF_2\alpha$ (Dinoprost)	20	20 (100)	08 (40.0)	217
	1st injection	08	08 (100)	04 (50.0)	
	2nd injection	12	12 (100)	04 (33.33)	

to oestrus synchronization and conception rate in buffaloes by using two injections. The mean time of onset of oestrus after 1st and 2nd injections was 95.5 ± 0.7 and 96.7 ± 1.2 hours, while duration of oestrus was 25.5 ± 2.1 and 27.0 ± 4.4 hours, respectively. The pregnancy rate was 50% and 33.3% following 1st and 2nd injections, respectively. During oestrus the progesterone concentrations in milk varied from 0.1 - 0.6 nmol/L while in pregnant buffaloes it varied from 10.3 - 20 nmol/L. It was concluded that Dinoprost could be used for synchronization of oestrus for controlled breeding program in buffalo cows.[217]

Prevalence of surgical disorders in buffaloes

The reports on the prevalence of surgical disorders in buffalies are very limited in Bangladesh and are mainly reported from Mymensingh district (Table 30).

Table 30. Prevalence of surgical disorders of buffaloes in Bangladesh

SN Disorders	Districts	No. of buffaloes	Prevalence No. (%)	Reference No.
01. Dehorning	Mymensingh	319	04 (01.25)	193
02. Lameness	Mymensingh	319	02 (00.63)	193
03. Rectal prolapse	Mymensingh	319	01 (00.31)	193
04. Skin wound	Mymensingh	319	02 (00.63)	193
05. Medial patellar desmotomy	Patuakhali	68*	68 (100)*	218
06. Cutaneous nodules	Mymensingh	326	05 (1.53)	196
07. Subcutaneous abscess	Mymensingh	705	08 (01.13)	192,196
08. Coenurus cerebralis	Mymensingh	1	01	219
09. Undiagnosed	Mymensingh	57	17 (29.82)	194
10. Skin fibroma	Mymensingh	1	01	220

*Clinical cases 100% recovered post-surgery

Mastitis in buffaloes

Mastitis is characterized by physical, chemical and bacteriological changes in the milk and pathological changes of the udder of buffaloes resulting decreased quality and quantity of milk production. Mastitis has primarily two forms, clinical mastitis (CM) and sub-clinical mastitis (SCM). The CM usually has all the five cardinal signs of udder inflammation (redness, heat, swelling, pain and loss of milk production) and hence can be easily diagnosed in buffaloes without any laboratory test mainly based on these apparent cardinal signs and symptoms and palpation of udder. The SCM is hidden and no apparent change in milk and therefore laboratory tests are required for diagnosis of SCM especially with the indirect tests for the diagnosis of SCM to detect the number of leukocytic cells present in the milk by using California Mastitis Test (CMT), Surf Field Mastitis Test (SFMT), White Side Test (WST) and others and bacterial isolation and identification. Mastitis is usually associated with reduced milk production, decreased quality of milk constituents, increased treatment cost, increased labor, presence of antibiotic and microbial residues, milk withheld during treatment and premature culling of

dairy animals. Risk factors for mastitis are calf suckling, folded thumb method of milking, uneven floor, poor hygiene, delayed detection of SCM, poor nutrition and allied diseases have been reported to be associated with high prevalence of mastitis.

The overall prevalence of 5.06% CM and 30.09% SCM are found based on the analysis of all available inland reports on buffaloes in Bangladesh (Table 26). Some individual reports showed 23.68% CM and SCM in 31.57%[153] and 32.5%[209] buffalo cows. However, the analysis of inland reports reveal that the prevalence of SCM based on animal-wise varies from 25.0 to 70% and quartier-wise from 23.13 to 32.50% (Table 31).

Table 31. Prevalence of SCM and its association with milk yield in buffaloes in Bangladesh

SN	Tests used	No. of buffalo tested	Positive No. (%)	No. of quarter tested	Positive No. (%)	SN	Daily milk yield (liter)	No. of animal tested	Positive No. (%)	Ref. No.
01.	CMT	40	13 (32.50)	160	45 (28.13)	1.	0.5-1	13	4 (30.77)	209
02.	CMT	400	221 (55.25)	-	-	-	-	-	-	221
03.	BMT	400	175 (43.75)	-	-	-	-	-	-	221
04.	CMT	30	21 (70.00)	-	-	-	-	-	-	222
05.	CMT	30	17 (56.66)	120	39 (32.50)	-	-	-	-	222
06.	WST	40	11 (27.50)	160	41 (25.62)	2.	>1-2	20	7 (35.00)	153
07.	WST	30	16 (53.30)	120	35 (29.16)	-	-	-	-	222
08.	WSDT	40	11 (27.50)	160	41 (25.62)	3.	>2-3	07	2 (28.57)	153
09.	ST	40	10 (25.00)	160	37 (23.13)					222
10	SFMT	30	15 (50.00)	120	32 (26.66)					222
11.	SDT	40	10 (25.00)	160	37 (23.13)					222

CMT = California Mastitis Test WST = White Side Test WSTD = White Side + Dye Test
ST = Surf Test STD = Surf + Dye Test BMT = BLRI Mastitis kit

The highest prevalence of SCM was recorded at 9 to 12 years of age (23.33%), 4th parity (16.67%) and late lactation (30.0%). The daily average milk production was insignificantly decreased in SCM affected buffaloes (4.5 ± 0.72 liter) than buffaloes without SCM (4.8 ± 0.88 liter) mastitis.[222]

Among the indirect tests used for the diagnosis of SCM in buffaloes, CMT has been reported to be highest efficacy (Table 27). [153,222] However, any of these indirect tests can be used to detect SCM under field conditions (Table 31).

A wide variety of bacteria has been reported to be associated with mastitis in buffaloes and it appears from this report that at least six types of bacteria have been isolated and identified in milk samples of apparently healthy buffaloes of Bangladesh (Table 32).

The Staphylococcus spp. (30.77%) has been reported to be most common pathogens, followed by Streptococcus spp. (20.51%), Bacillus spp. (15.39%) and Escherichia coli (12.82%) as single infection and 12.82% as mixed infection in SCM of buffaloes[222] The isolated bacteria from the Bagerhat Buffalo Development Farm showed resistance to ampicillin, amoxicillin and

Table 32. Prevalence of bacteria in SCM cases and their resistance status in buffaloes

Bacteria isolated from SCM			Resistance status % (Used 5 isolates /bacteria for test)							
SNBacteria	No. tested	Positive No. (%)	GM	CIP	EF	CHL	AX	AM	STP	Ref. No.
01. Staphylococcus spp.	39	12 (30.77)	0	0	0	0	60.0	40.0	80.0	222
02. S. aureus	30	21 (50.0)								223*
03. Streptococcus spp.	39	08 (20.51)	0	0	0	0	60.0	40.0	60.0	222
04. Bacillus spp.	39	06 (15.39)	0	0	0	0	60.0	60.0	80.0	221
	30	02 (04.76))	-	-	-	-	-	-	-	223*
05. Escherichia coli	39	05 (12.82)	0	0	0	0	20.0	40.0	40.0	222
	30	12 (28.57))	-	-	-	-	-	-	-	223*
06. Proteus spp.	30	01 (02.38)	-	-	-	-	-	-	-	223*
07. Enterobacter	30	06 (14.29)	-	-	-	-	-	-	-	223*
Sub-total (Single)	39	31 (79.49)	-	-	-	-	-	-	-	222
08. Mixed infection	39	05 (12.82)	-	-	-	-	-	-	-	222
09. Unidentified	39	03 (07.69)	-	-	-	-	-	-	-	222

n = No. of samples GNT = Gentamicin CIP = Ciprofloxacin EF = Endrofloxacin
CHL = Chloramphenicol AX = Amoxicillin AM = Ampicillin STP = Streptomycin
*Drug sensitivity and resistance patterns have been presented overall not species-wise which could not be utilized.

streptomycin whereas other tested antibiotics were sensitive to these isolated organisms (Table 32). Buffaloes have been reported to be less susceptible to mastitis than cattle.[209] The SCM is six times more common than CM and causes greatest overall losses in most dairy herds (Table 26). This review highlights the important bacterial pathogens associated with SCM in buffaloes with their antibiotic sensitivity and resistance to antibiotics in Bangladesh that could help to select the antibiotics in the treatment and prevention of mastitis in buffaloes in local conditions. Therefore, regular testing of milk of apparently healthy animals would be suggested to reduce the prevalence and economic losses due to SCM in buffaloes in Bangladesh.

Buffalo calf health management and diseases

The success of buffalo dairy industry depends on better management practices and survival of the buffalo calf produced because of the future dairy herd solely depends upon the successful raising of young calves. Healthy calves are not only essential for preserving and maintaining good quality germ plasm but also required for the development and profitability of the buffalo farms. The growth performance of calves in rural stallholder farmers revealed poor health condition which indicates lack of awareness among farmers on scientific health management and control of diseases. Restricted milk feeding, high prevalence of gastro-intestinal parasites and faulty management system might lead to poor health condition of buffalo calves in Bangladesh. The calf pneumonia (22.4%), gastro-intestinal parasites, bacterial enteritis in buffalo calves have been reported to be widely prevalent in Bangladesh. [40,153]

Evaluation of the management system of 140 smallholder buffalo farms have been reported that only 4.3% farmers fed colostrum to calves soon after birth, 13.6% farmers dewormed and 12.9% vaccinated against anthrax and FMD. Sick calves have been treated mostly by the owner (59.3%) compared with treated by Vet (12.9%) and quack (27.8%).[224] The helminthiosis (20.3%) have been reported to highest prevalence, followed by malnutrition (13.2%), indigestion (12.4%) and navel-ill (9.3%) in buffalo calves (Table 33). The overall 5.6% prevalence of FMD in buffalo calves has been reported based on hospital records.[225]

Table 33. Prevalence of diseases in buffalo calves (n = 236) under smallholder farmers[224]

SN Diseases	No. (%) +ve	SN Diseases	No. (%) +ve	SN Diseases	No. (%) +ve
01. Fever	18 (07.6)	02. Diarrhea	13 (05.7)	03. Pneumonia	11 (04.5)
04. Anorexia	13 (05.3)	05. Calf scour	04 (01.8)	06. Malnutrition	31 (13.2)
07. Helminthiais	48 (20.3)	08. Metabolic	18 (07.8)	09. Indigestion	29 (12.4)
10. Ectoparasites	11 (04.5)	11. Eye diseases	08 (03.4)	12. Navel-ill	22 (09.3)
13. Wound	08 (03.4)	14. Abscess	02 (00.8)		

Diarrhea in buffalo calves

Calf diarrhea especially neonatal calf diarrhea is a multi-factorial syndrome which is characterized by passage of soft abnormal color fluid feces, usually white to yellow green, loss of body weight, becoming lean, dehydration, metabolic acidosis and mortality. Neonatal and young calves are highly susceptible to diarrhea caused by enteric microbes and parasitic pathogens and non-infectious factors including immunological, nutritional, environmental and managemental factors. Diarrhea may occur as a consequence of stress, improper sanitation and sudden feed changes. In addition to calf mortality, diarrhea costs of treatment, diagnostics, labor, veterinary medical intervention, chronic ill-thrift and impaired growth performance

Bacterial diarrhea in calves is commonly caused by enterotoxegenic E. coli and Salmonella. Among E. coli pathogroups, ETEC strains that causes a watery diarrhea and weakness in 1 to 4 day old newborn calves and death is usually occurs within 24 hours due to severe dehydration.

Diarrhea due to Salmonella infection is watery and mucoid with the presence of blood and fibrin and recovered carrier and infected animals can serve as source of infection for other animals and even humans. Among the virus diarrhea, rotavirus has been reported in diarrheic buffalo calves from Bangladesh.

Rotavirus diarrhea in buffalo calves

The rotavirus (genus: *Rotavirus*, family: *Reoviridae*) are the leading cause of diarrhea in both the cattle and buffalo calves.[226] Rotavirus was detected in fecal samples of buffalo calves of both diarrheic (11.98%) and non-diarrheic (3.0%) buffalo calves by using ELISA (Table 34). An association between diarrhea and rotavirus infection was recorded in buffalo calves below one month of age in both diarrheic (27%) and non-diarrheic (7%) calves. Rotavirus infection in diarrheic calves was found to be highest in winter (16.7%), followed by summer (9.1%) and lowest in the rainy (7.7%) season.[227]

Table 34. Diarrheic and non-diarrheic and season-wise prevalence of rotavirus in buffalo calves[227]

SNAge Groups (months)	Diarrheic calves No. tested	Positive No. (%)	Non-diarrheic calves No. tested	Positive No. (%)	Seasons	No. tested	Positive No. (%)
1. <1	041	11 (26.83)	27	2 (7.41)	Winter (Nov.-Feb.)	102	17 (16.67)
2. 1-6	102	12 (11.76)	39	2 (5.13)	Summer (Mar.-June)	088	08 (09.09)
3. >6-12	099	06 (06.06)	42	-	Rainy (July-Oct.)	052	04 (07.69)
Total	242	29 (11.98)	108	4 (3.70)		242	29 (11.98)

Mortality of buffalo calves

Calf mortality is associated with the type of housing, feeding, management practices, weather, external and internal parasitic infestation and infectious diseases, especially causing septicemia and enteritis. Buffalo calves were fed 1.0 to 1.5 liter colostrum daily followed by milk in gradually decreasing quantity up to 30 days before introduction of calf starter.[228] Colostrum feeding helps neonatal calves to make a defense against infectious diseases. Mortality of 131 buffalo calves up to one year of age has been reported, of which 64 (48.85%) Nili-Ravi and 67 (51.15%) cross-bred buffaloes (Table 32).[229] Whereas overall 24.29% buffalo calf mortality has been reported from the same Buffalo Development Farm in other report (Table 35).[73] Feeding and management of the buffalo farm have been reported to be appeared well but heavy loss of buffalo calves recorded as a serious problem in the farm.[229]

Mortality represents the ratio of deaths occurring from a particular cause divided by the total population at risk (Mortality = Deaths ÷ Population at risk × 100]. Case fatality rate is the ratio of deaths occurring from a particular cause to the total number of cases due to the same cause [Case fatality = Deaths ÷ Cases × 100]. Whereas proportionate mortality is the ratio within the death cases which has no any direct relation either with affected cases or population at risk, so the reported proportionate percentage values has no epidemiological and statistical significance (Table 35)

Table 35. Buffalo calf mortality status in the BBDF'B and Smallholder farms in Bangladesh

SN Year	No. of buffalo calf borne				Mortality (No.,%) of buffalo calves*				Ref. No.
	Nili-Ravi	Cross	Local	Total	Nili-Ravi	Cross	Local	Overall	
1. 1999	124	156	-	280	46 (37.1)	22 (14.1)	-	68 (24.29)	073
2. 2003*	-	-	-	-	64 (48.85)*	67 (51.15)*	-	131 (?)	229
3. 2010-11	-	-	482	482	-	-	70 (14.5)	070 (14.5)	224**

BBDF'B = Buffalo Breeding and Development Farm, Bagherhat, Bangladesh
? = No. of calf borne not recorded & no overall mortality rate - = Not classified the crossbred calves
*Proportionate case fatality rates are epidemiologically and statistically insignificant application
**Data of 140 buffalo smallholders' farms

An overall 14.5% (n = 70/482) buffalo calf mortality has been reported in smallholders' farms with highest mortality (74.5%; n = 50) at the first three months of age in comparison to 4-6 months (2.7%; n= 13), > 6 to 12 months (1.0%; n= 5) age groups.[224] Excessive rainfall and damp weather in the coastal area increased rate of infectious disease which might be caused higher mortality. Female buffalo calves are more vulnerable than the male calves. However, the variation of calf mortality rates might be due to different buffalo breeds, cross-bred and indigenous types and management system adopted by the farmers and farmers.

Toxoascariasis in buffalo calves

Toxoascariasis is caused by *Toxocara vitulorum*, an intestinal ascarid parasite of water buffaloes and cattle worldwide including Bangladesh.[174-176] It causes morbidity and mortality in calves, which typically become infected early suckling by ingesting larvae excreted in the colostrum and milk.[230-232] The ingested larvae are usually matured at adult worms in the duodenum of infected calves and produce large number of eggs during the patent period of four weeks. Most of the infected calves are able to clear the parasite due to strengthened and acquired immunity at the eight weeks of age.[232] However, heavy infection is usually associated with clinical disease and mortality in calves, and the disease is characterized by severe anemia, diarrhea, weight loss and anorexia in buffalo calves of 1 to 3 months of age. Therefore, buffalo farmers should be aware about the epidemiological risk factors and impact of *T. vitulorum* infection in calves and treat their calves at the age of 2 to 3 weeks with an effective anthelmintic. It appears that the health and management practices of buffalo calves in both the buffalo farms and smallholder farmers' levels is highly neglected and however the pattern of calf rearing in all the smallholder farms are almost similar art rural levels. It is clear from this review that the appropriate calf management practices including colostrum feeding, navel treatment and control of helminthes parasites could reduce the morbidity and mortality rates of buffalo calves.

Constraints of buffalo production

Buffaloes are widely distributed throughout the country but most of the buffalo farms are concentrated in the southern parts and all of which are provided as one of the main livelihood support to the buffalo farmers in Bangladesh. Buffalo development is mainly constrained by three factors which include inadequate feed and fodder resources, prevalence of wide spread diseases and parasites and low productivity due to the low genetic potential of the indigenous buffaloes in Bangladesh. These indigenous buffaloes are mostly reared at stallholder farmers with undernourished and managed under primitive feeding and breeding systems. It appears from this review that the constraints of buffalo production in developing world especially in Bangladesh may be categorized into seven types which include ① Socio-economic, ② Breeds and breeding, ③ Feeds and fodder, ④ Management, ⑤ Diseases and parasites, ⑥ Technological and ⑦ Marketing.[6,7,19,189]

① The **socio-economic** constraints include low input service, lack of public awareness, less interest in buffalo farming and necessary fund. The highest of 33% family income have showed to be derived from buffalo rearing followed by service, business, farming and

livestock except buffalo.[19] However, the 80% smallholder famers have used own capital, 13% used bank loan and 7% used NGO loan for buffalo production.[119]

② The **breeds and breeding** constraints include majority of buffaloes are indigenous with low productivity, seasonality of reproduction, inadequate knowledge to detect estrus, non-availability of AI facilities, lack of good breeding bull, poor conception rate and no system to follow the performances of crossbred progeny testing program at field level.[6,7,14,51,189]

③ **Feed and fodder**- there is a requirement of 70 million metric tons of green grass for animals in a year but produced only 24 million metric tons in Bangladesh. Accordingly, there is a deficit of animal feeds for about 60% which are hampering the livestock development to a great extent.[233] The constraint of feeds and fodder includes non-availability of green and dry fodder, grazing land and high prices of concentrate ingredients.[6,7,189]

④ The different **management system** of buffaloes like extensive, intensive, semi-intensive, bathan system in open yard at day-night, global warming and climatic changes includes poor animal husbandry practices.[6-8,69]

⑤ Wide spread buffalo **diseases and parasites** are one of the major constraints as high as 49.10 to 64.2% buffaloes are affected with one or more species of gastro-intestinal parasites, bacterial diarrhea caused by *E. coli* (62.5%) and *Salmonella* spp. (29.16%), 23.68% with clinical mastitis and 31.57% sub-clinical mastitis.[209] In addition, high buffalo calf morbidity and mortality rates,[73,229,234] high price of drugs and inadequate veterinary medical facilities are the major constraints of buffalo production in Bangladesh. The prevalence of snail-borne trematode (SBT) and the vector snails are highly endemic in Bangladesh including Saint Martin's Island and proper attention is needed to control these infections.[168] The wallowing behavior or submergence to muddy water predisposes the water buffaloes to different diseases like leptospirosis, brucellosis, fascioliasis, amphistomiasis and schistosomiasis and also acts as a reservoir host for zoonotic diseases like schistosomiasis, rotavirus infection, leptospirosis, brucellosis and tuberculosis.[20]

⑥ **Technological** constraints- lack of technical knowledge on buffalo production, very slow adaptation of AI and other reproductive biotechnology, limitation of the technology to detect adulteration and microbial load in milk and meat. Deficient and imbalanced nutrition based on stage of reproduction is a major constraint responsible for low productivity of animals, whereas balanced ration contributes to improve animal output as well as to reduce both the cost of production and emission of greenhouse gases per unit of animal product.

⑦ **Marketing** constraints- lack of knowledge about the quality of buffalo milk and meat and their price, problems in milk transportation and lack of awareness in marketing milk in Bangladesh. Buyers, sellers and producers of milk and meat have no accurate information and coordination.

Self-plagiarism for publication of articles

Plagiarism is the research misconduct and an assault on integrity of scientific research. It can be self-plagiarism and plagiarism from others. Most important self-plagiarism practiced is the duplicate publication, when substantially similar data, idea and article published to different journals with or without editing, with or without changing of authorship orders.[235] It appears

from this review that multiple articles have been published with same data or in duplicate in different journals especially on the histology on muzzle,[130/236] partial repetition of data on parasitic diseases,[172,173] bacteria isolated from trachea and lungs[150/151] and reproductive performances of buffaloes. [82/83,87/88] Authors, reviewers, editors, academicians, readers and science community need a more caution approach to deal these types of articles with inadequate and inappropriate data and self-plagiarism.

CONCLUSIONS

The smallholder buffalo dairy farmings have been reported to be an important and have the potential to poverty alleviation, food security, improved family nutrition and income and employment generation. There is a need for technical and institutional intervention to alleviate the identified constraints through dissemination of appropriate technologies for better disease prevention strategy, establishing the reliable milk market, availability of veterinary medical services with convenient price of drugs, availability of feeds and fodder, cross-breeding program through AI with quality semen and awareness of the dairy buffalo and industry. The low productivity of indigenous buffalo is mainly due to genetic characters and poor quality nutrition. Therefore, the genetic improvement with crossbreeding program especially with high milk yielding NiIli-Ravi and Murrah breeds, balance ration and good management are required to increase production. However, the delayed maturity, seasonal breeder, prolong calving interval, poor signs of heat and low conception rates in buffalo species are the main obstacle for the reproductive efficiency which could be minimized with controlled reproductive management through synchronization with AI program with proven bull semen. The embryo transfer, *in vitro* embryo production and nucleus transfer are remained at the costly experimental stage. If their costs are reduced these latest techniques offer the opportunity to accelerate the genetic gain in the buffalo industry with the provision that they are used in conjunction with efficient national progeny testing and sire evaluation. Smallholder buffalo farmers need proper education, training and extension services about scientific management of dairy buffaloes and their calf production and health care to ensure the milk and meat production at profitable level along with the best quality of germ plasm of buffalo for the sustainable dairy development in Bangladesh. This emphasizes on production and health composite curriculum at both the graduation and training levels that warrant immediate attention and action to cope up with the challenges on the differences on the educational training and field requirement for the national interest to increase the milk and meat production for the fast-growing demand of animal protein requirement for the people of Bangladesh.

ETHICAL APPROVAL

This review article does not contain any studies with animals or human participants performed by the authors. Therefore, ethical approval is not required for this review article.

CONFLICT OF INTEREST

All data reviewed and analyzed were from published reports in the available journals. The process and publication of this review article did not receive any specific grant from funding agencies in the public, commercial or not for profit organzations.

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