

## A SIX-DECADE REVIEW: RESEARCH ON CATTLE PRODUCTION, MANAGEMENT AND DAIRY PRODUCTS IN BANGLADESH

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### ABSTRACT

**Background:** Historical changes in the demand of animal protein sources (milk & meat) for human consumption have been largely increased due to increased growth of human population, income and urbanization in Bangladesh. Research on cattle production and management especially cattle breeding, feeds and fodders, milk production and products have contributed to increase potential production and genetic gains of cattle. A comprehensive review on the published inland research reports on cattle production, management and dairy products are lacking in literature which is required for further research for the cattle development and production.

**Objectives:** An attempt to review on the published inland research reports on the advances in science and technology on cattle production, management and dairy products in Bangladesh

**Materials and Methods:** A systematic literature review of research articles on cattle production, management and dairy products published between 1962 and 2020 from Bangladesh has been reviewed. A total of 1185 research articles on cattle production, management and dairy products supported with some international related articles have been reviewed and analyzed.

**Results:** Research data on cattle production, management and dairy products are compiled from 1185 different research reports supported with some international reports. This review covers the status of cattle breeds and varieties with tabulated summary of 21 reports on draught cattle, 83 on fodder production, 97 on nutrition, feeds and feeding, 88 on trials of different feed formulations in non-dairy cattle and 68 on dairy cattle, 5 on the effects of heat stress on health and production, 39 on fattening of cattle, 27 on genetics and breeding, 75 on semen and AI, 20 on factors associated with conception rate (CR), 8 on oocyte and embryo collection, 9 on genotypes of dairy cows, 7 on management of smallholder dairy farms, 48 on milk production status of dairy cattle, 32 on economics of rearing cattle, 99 on productive and reproductive performances of cattle, 7 on estrus and pregnancy diagnosis, 7 problems of dairy farmers, 23 on preservative and adulteration of milk, 20 on constituents and methods of sweet preparation, 11 on cheese preparation, 9 on ice-cream, 56 on yoghurt, 4 on beef cattle production, 34 on birth weight, and 15 on calf rearing including calf milk replacer and calf starter.

**Conclusions:** Data based reports are important for priority setting and targeting with mandate for cattle development and increase production. Currently, one of the biggest gaps in the inland datasets on cattle research and this review addresses this gap by bringing together in a review and highlighting some of the major findings. Cross-breeding remains an attractive option for cattle improvement because of the quick results that can be obtained by its use and the potential benefits it has farmers. This review would serve as an archive of research reports on cattle production, management and dairy products for the concerned academicians, research scientists, organizations and government for future planning for education, research and extension on cattle production.

Keywords: Systematic review, Six decades, Cattle, Management, Production, Dairy products, Bangladesh

Article Info: Article Code No. © LEP: JVMOHR/0021/2020

Received: 15 July 2020 Revised: 15 Nov 2020 Accepted: 10 Dec 2020 Published: 30 Dec 2020

**Citation:** Samad MA (2020). A six-decade review: research on cattle production, management and dairy products in Bangladesh. *J. Vet. Med. OH Res.* 2 (2): 183-404 [doi:10.36111/jvmohr.2020.2(2). 0021]



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## INTRODUCTION

The livestock sector especially cattle production is rapidly changing in response to globalization and growing demand for animal source foods due to increase population growth, increase income and rapid rate of urbanization that changes in food preferences for people. The health and quality of animal is influenced by genetics, management practices, nutrition and environment. The main target of animal production includes good quality healthy animals that reach full production potential and a quality nutritious and safe food supply. Animal production is the science and art of rearing domestic animals with the subjects as animal behavior and management, genetics and breeding, reproduction, nutrition, meat science, dairy science and technology<sup>1</sup> The production of cattle for various purposes especially dairy, beef, hides and other products which can be primarily categorized into dairy industry and beef industry. Cattle domestication and production have a long history and recognized as a most important livestock species because of their production and role in human culture. Many breeds and varieties of cattle that differ in appearance, performance and environmental adaptation are kept on all inhabited continents but the historic origin of the diverse phenotypes is not always clear. Cattle production systems integrate responsible management strategies, environmental principles and stewardship of property and economic awareness and viability whereas management strategies are uniquely linked with forage production and nutritive value, herd size, housing systems and opportunities to match forages with animal requirements for production.<sup>2</sup> Cattle are the most common type of large domesticated ruminant livestock of the genus *Bos* under family *Bovidae*. *Bos indicus* and *Bos taurus* are the two distinct species of cattle. The *B. indicus* is the Indian sub-continent zebu (humped) cattle characterized by lower growth rate, smaller size, late sexual maturity, low production and comparatively more resistant to diseases, whereas the *B. taurus* (temperate cattle) is characterized by medium to heavy size, early sexual maturity and has high milk production potentialities. However, the farmers of Bangladesh have been rearing three types of cattle including indigenous, exotic pure breeds and their crosses for the three main purposes which include (a) milk production mainly from indigenous, some temperate and tropical breeds and their crossbred dairy cows, (b) beef production from fattening crossbred and indigenous bulls especially for Eid-ul-Azha and commonly reared both bull and heifers and also all types of culled cattle including cows and bullock and recently introduced Brahman beef cattle, and (c) draught animal power (DAP) mainly by using bullock and also cows.<sup>3,4</sup> Bangladesh is primarily an agriculture-based country and the majority of the rural households adopt a mixed farming system by simultaneous cultivating crops and rearing livestock. Livestock contributes as protein food supply (milk & meat), source of income, asset saving, source of employment, soil fertility, livelihoods, transport, agricultural traction and agricultural diversification and sustainable agricultural production. The livestock sub-sector provides full time employment for 20% of the total population and part-time employment for another 50% in Bangladesh.<sup>5</sup> Research is the most direct approach to improve the methods of animal health and production. It appears from the review of available literature that the first published research report on AI in cattle was made in 1964 from the then East Pakistan<sup>6</sup> and an overview of livestock research reports of the twentieth century in Bangladesh has been reported.<sup>7</sup> Later on the 50-year review on the prevalence of clinical diseases and disorders of cattle,<sup>8</sup> review of pre-clinical and clinical research reports on small ruminants<sup>9</sup> and review on research findings on buffalo health and

production<sup>10</sup> in Bangladesh has been published. An up-to-date analysis shows that a huge number of research articles have been published on the different aspects of cattle production and management from Bangladesh. It is of value to look back and see where we have come from on the concerned research which would be required for the future planning of research especially on cattle production, management and dairy products. Therefore, an attempt was made to review and compile the up-to-date available research reports on cattle production, management and dairy products in Bangladesh.

## **MATERIALS AND METHODS**

The research reports on cattle production published mainly in journals over the last six decades from 1964 to 2020 from the then East Pakistan and now Bangladesh have been reviewed and analyzed during the period for two years from 2019 and 2020 as described.<sup>9,10</sup>

### **Research findings on cattle production**

Bangladesh is a home to different cattle varieties and crosses but it is difficult to identify these animals as system has not yet been developed to keep record of cattle breeding at either farmers' or national levels and only they can be identified based on their phenotypical characteristics, history of animals and somewhat available of cattle at the regions. The most commonly found cattle varieties and breeds in Bangladesh are Red Chittagong cattle (RCC), Pabna variety, North Bengal Grey (NBG), Munshigonj (Mirkadim) variety, Madaripur type, Dinajpur Dwarf cattle (DDC), Non-descriptive native or local type, crossbred and some imported exotic breeds including Holstein-Friesian, Sahiwal, Sindhi and Jersey.<sup>11-13</sup> These so called varieties of cattle have neither been identified (either by phenotypic and genetic characterization) nor has any objective study been made on their conformation or productive and reproductive performance with larger sample sizes in-situ.<sup>14</sup> There is no specific cattle breed has yet been established in Bangladesh but with long natural selection and occasionally imported bulls some improved deshi varieties of cattle exist in some districts in Bangladesh. The Holstein-Friesian, Jersey, Sahiwal, Sindhi, Haryana, Australian Sahiwal-Friesian have been imported in different times to improve the production potentialities of the local cattle. As a result of this program, some pure exotic breeds, their crosses and up-graded cattle are found in the government dairy farms, commercial private dairy farms, milk pocket areas and in urban and semi-urban areas of Bangladesh. With rapid expansion of crossbreeding and urbanization, the indigenous cattle genetic resources of Bangladesh are under threat of extinction.<sup>13</sup> Major constraints for cattle rearing and development are mainly associated with lack of specific cattle breed, unplanned cross-breeding program, cost-effective feeds, morbidity and mortality of cattle, inadequate veterinary medical services and unregulated market price for cattle and its products in Bangladesh.

There are about 24.086 million cattle population in Bangladesh where about 6 million are dairy cattle and its 85 to 93.3% indigenous Zebu type (*Bos indicus*) and only 6.7 to 15% crossbreeds.<sup>13,15-17</sup> Cattle are mostly reared by the smallholder farmers but the living standard of these farmers have not been improved enough as required may be due to rearing indigenous cattle.<sup>18,19</sup> However, almost 75% women are involved moderately to high levels participation in livestock and fisheries activities in rural Bangladesh.<sup>20-22</sup>

### Non-descriptive indigenous zebu cattle

Cattle in Indo-Pakistan sub-continent belonging mainly to species *Bos indicus* are also known as zebus or humped.<sup>23</sup> India is believed to be the center of origin of zebu cattle (*B. indicus*) which later spread to Africa and southeast Asia.<sup>24</sup> There are 43 registered native indigenous cattle breeds in India ranging from dairy to pure draught types<sup>25</sup> and about 75 different breeds of zebu cattle are known in the world.<sup>26</sup> The Indian indigenous cattle have been classified into three groups viz. (① Milch purposes (1000-1500 kg / lactation) e.g. Sahiwal, Red Sindhi, Gir and Deoni, ② Dual purpose (500-1000 kg / lactation) e.g. Ongole, Harijana, Kankrej, Gaoao, Tharparkar, Mewati, Ratti, Dangi and Nimadi and ③ Draught purpose (< 500 kg / lactation) e.g. Hallikar, Amritmahal, Khillari, Kangayam, Nagori and others.<sup>27</sup> Zebu cattle differ mainly in the shape and firmness of the hump, horn size, ranging from long-horned to very short-horned or even almost rudimentary horns and horn shape.<sup>28</sup> Zebu cattle have evolved under low levels of selection which has led to high adaptability of these breeds to harsh environment, resistance to tropical diseases and parasites and sustenance on low quality nutritional regimes. Pure zebu cattle can vary in color with coats ranging from red to grey. Their most distinctive features are their large hump, large horns, and even large ears that drop downwards. Zebu cattle are known to be less fertile and have lower levels of milk production than *B. taurus* breeds, but their better adaptation to the environmental conditions make them more likely to reproduce successfully in the tropics. Cross-breeds incorporate the environmental adaptation of zebu cattle with the higher production of *B. taurus* as well as the benefit of hybrid vigor.<sup>29</sup>

Out of 24.5 million cattle population, of which 80.0 to 90.0% are of non-descript indigenous in origin zebu type having developed hump which are distributed all over Bangladesh (Table 1).<sup>13,30,31</sup> There is no breed of zebu cattle of Bangladesh but it is assumed that they have evolved in this country over the centuries for natural selection and farmer's interest on draught power to perform agriculture practices.<sup>13</sup> These indigenous zebu cattle are profitably reared with minimum climatic stress and thrive well in hot and humid temperature and maintaining phenotypic and productive performance in rural Bangladesh.<sup>32</sup>

Indigenous cattle population of Bangladesh are mainly *B. indicus* type encompassing various cattle genetic resources like non-descript, RCC, Pabna variety, NBG, Madaripur and Munshiganj varieties are localized in some areas in Bangladesh.<sup>33</sup> These indigenous cattle have well adapted in the extreme tropical climates, ability to maintain body condition on low quality feed stuffs, reputed to give birth regularly, comparatively resistance to certain diseases with lower calf morbidity and mortality and suitable for hard working in hot, humid and rainfall condition. The varied morphometric, productive and reproductive traits of native cattle have been reported from Bangladesh.<sup>34-36</sup> Some characteristics of indigenous cattle have been reported as (a) Small size and hence lower metabolic heat production, (b) Regular breeder, (c) Lower calf mortality (< 5 to 6%), (d) High variation in phenotypic performance, (e) Better utilization of low quality roughages and (f) Stabilize the existing production and marketing system.<sup>37</sup> The observed coat color of zebu cattle in Magura district have been reported as reddish (29.54%), black with white spot (25%), white (18.18%), black (11.36%), grey (9.09%) and ash (6.82%).<sup>38</sup> Some overall phenotypic characters of the indigenous zebu cattle have also been reported.<sup>13,32,33</sup>

- Their coat color varies from red, grey, white, black or a mixture of them in different proportion.
- They have prominent humps, deep shoulders, well-developed hind quarters but the head is slim

with pointed and crescent-shaped horns.

- The forehead is prominent, convex and broad like a bony shield.
- The overhangs eyes in such as way they appear to be partially closed and the animal shows sloppy appearance.
- Ears are long and pendulous and folded like a leaf with a notch at the tip.
- Horns are curved turning back at the tip.
- They have moderately developed dewlap: males have a large and pendulous sheath.
- The tail is long and whip like, hooves are medium-sized, and hair is short and glossy.
- Skin is loose and pliable, hipbones are prominent, udder is well developed including teat tips are round.
- Adult weigh between 150 to 250 kg and yields 47 to 52% of its weight of meat.

The non-descriptive indigenous zebu cattle populations have declined due mainly to the mechanization in agriculture and the introduction of high yielding crossbreeding program.

### **Pabna variety cattle**

Pabna variety of cattle, as the name suggests is from Pabna district especially found in Shahzadpur, Bera and Sathia upazila but it is also distributed in Sirajgonj district as well as areas in Tangail, Dhaka, Manikgonj and Bogura districts (Table 1). They are actually crossbred of imported Sahiwal, Sindhi and Haryana bulls with the native cattle and an intensive selection for milk production for long periods.<sup>39</sup> The main features of large size body than their native counterparts, live weight 250 to 400 kg and high milk production in comparison to other local varieties of cows. The coat color is usually red or gray or a mixture of both and mostly deep grey to white with different shades in male cattle. Their physical features like hump and shoulder are similar to zebu cattle. Skin pigmentation pattern have been reported as light red dominated for coat color in both cattle population while black color is most frequently observed in muzzle, eyelid, eyelash, horn, hoof, dew claw and tail switch.<sup>40,41</sup>

The average milk production of indigenous cattle ranged between 0.50 to 2.50 liters per day while 4.79 liter / day in Pabna variety.<sup>42</sup> Unique dairy cattle herd of different cross-bred are available in Baghabari region of Milk-Vita. The genetic admixture in dairy herd showed the combination of several breeds in which the frequency of Holstein-Friesian has the highest regarding predominant individual breed characteristics followed by Jersey and Sahiwal with local cows (mainly Pabna cattle). One of the major reasons of this admixture is random and unplanned AI between or among breeds which also affecting the performance of cattle population and such situation originated from non / zero-record keeping system.<sup>16</sup>

### **Red Chittagong cattle (RCC)**

The RCC variety is found in the coastal plain zone of the Chittagong district as well as to a smaller extent in Noakhali and southern regions of Comilla (Table 1). The concentrated areas of RCC have been reported in Anwara, Razoan, Hathazari, Chandanaish, Patiya and Bashkhali upazila.<sup>11,43</sup> They have distinct identity with attractive red body color, delicious milk and meat compared to other indigenous cattle make them to preferred in that region. The characteristic phenotypic features of RCC have been reported as: (a) Red coat color (deep to light), (b) Whitish red or brick red color muzzle, horn, hoof and eyes, (c) Narrow thin headed, (d) Flat forehead,

(e) Blocky as well as medium body sized, (f) Males are heavier than females, (g) Physical condition is very strong and stout, (h) Large tail with whitish switch, (i) Milk vein is compact and not so prominent, (j) Well developed hump in males but less prominent in females and (k) Prominent dewlap in males.<sup>43-45</sup> The morphological measurements of RCC have been reported to be increased significantly ( $p < 0.01$ ) with the advancement of age.<sup>35</sup>

The average birth weight is 15.4 kg with highest live weight gained at 30 months (122.8 kg) and then declined the live weight of RCC.<sup>46</sup> A typical RC bull weighs 250 to 400 kg and cow 150 to 250 kg and 48 to 52% meat of its actual weight. Horn length and diameter for male and female have been reported to be  $11.43 \pm 1.17$ ,  $11.68 \pm 1.08$  and  $10.84 \pm 1.13$ ,  $9.187 \pm 1.08$  cm respectively. The body length, body height and heart girth of cow and bull have been reported as 107.13 to 114.34, 105.94 to 107.71, 136.90 to 130.85 and 131.44 to 134.0, 124.46 to 125.0 and 165.45 to 168.0 cm, respectively. They have medium sized udder with their teats  $5.02 \pm 0.03$  cm in length and  $5.84 \pm 0.04$  cm diameter.<sup>43</sup>

Growth performance and reproductive potential of RCC based on phenotypic and genetic parameters have been reported.<sup>47-50</sup> The productive and reproductive performance RCC is very much promising and appreciable than other non-descriptive indigenous cattle available in Bangladesh.<sup>43,51</sup> The similar performance of RCC has been reported in both the intensive and traditional management system and equally suitable for both the systems of management.<sup>52</sup> The RCC has been reported to have similar body weight and growth performance in farm and field conditions that indicates their equal suitability in both management systems.<sup>46</sup> The estimation of adjustment factors for standardizing age and season corrected 305 days milk and heritability and repeatability of standardized milk yield,<sup>53</sup> feeding and management practices,<sup>54</sup> economic values for different economic traits,<sup>55</sup> socio-economic status of RCC farmers<sup>56</sup> and farmers' attitude toward rearing RCC<sup>57</sup> have been reported.

### **North Bengal Grey cattle (NBG)**

The NBG cattle are found scattered in the northern district of Bangladesh (Tista meander-flood plain and lower atria basin zone) especially in Rajshahi division (Table 1). This variety of cattle might have been originated from cross-breeding of local cattle with that of cattle imported from northern part of India for long period. A surveyed area of the north Bengal showed that about 54% of the total cattle population recognized as NBG variety.<sup>14</sup> The body is small, compact and less fleshy. The coat color of NBG cattle mostly deep grey to white with differing shades. The head is small and the color of the muzzles, eyelids and hooves is black. The neck region of adult cattle has an ashy shade which is more prominent and increased with age. The horns are small to medium and curved inward with pointed tips. The ears are small and erect with a sideways orientation and have pointed tips. The face is small and narrow with a flat forehead. The skin is tight, the dewlap is medium and the hump is small in cow and developed in bulls. The tail is long and reached to below the hock. They possess good body size and some draft features and famous as a cart bullock in the market.<sup>14</sup>

The major threat to native cattle are scarcity of pure native bulls, indiscriminate national cross-breeding program, lack of conservation and development program and farmers interest for cross-breeding for high production.

### **Munshiganj variety cattle (MVC)**

The MVC is also known as Mirkadim cattle get its name from an area in Munshiganj where they are farmed. However, this variety of cattle is distributed in Munshiganj, Manikgonj and adjacent region of the district (Table 1). These cattle are mostly of creamy to dull pinkish coat color with milk type body conformation have great demand as milk cow in the surrounding regions. Their skin are pigmented, muzzle, eye brow, hoof, horn and switch are black.<sup>58</sup> Some authors have presumed that this variety has evolved in the localities by selecting breeding and no authentic history of cross-breeding could be traced.<sup>45</sup> However, some authors reported that in addition to selective breeding since 1930's several attempts might also been made scatter to increase their production potential through infusion of foreign genes both sub-continental and temperate for different periods to improve the genetic resources of cattle.

The MVC is one of the recognized milk type varieties of cattle with good potentialities but its population is rapidly declining due to unplanned crossbreeding program with exotic genetic resources to produce high yielding crossbred cattle without any breeding policy, conservation and development of MCV.<sup>59</sup>

### **Dinajpur Dwarf cattle**

The dwarf cattle in Dinajpur district are comparatively smaller in size than most of the recognized varieties or types of indigenous cattle but their coat color showed remarkable variation. The average live weight of yearling bull is 91.32 kg, bull 109.10 kg, and cow 89.74 kg.<sup>12</sup> Dwarf cattle can be promising cattle type with low feed intake and high milk yield in harsh climatic condition in Northern part of Bangladesh. Morphometric traits have been reported to be smaller than almost all the cattle available in Bangladesh. Productive and reproductive traits are more or less similar with the other cattle. Major constraints of dwarf cattle production are lack of quality breeding, lack of feeds and their cost, disease outbreaks, lack of effective vaccines and medicines and fluctuating market prices.<sup>12</sup>

### **Exotic and crossbred dairy cattle**

The then East Pakistan and Bangladesh government were imported different exotic cattle and semen to upgrade the indigenous cattle in different time. This cross-breeding program has been launched in 1958 by the Directorate of Livestock Service (DLS) with artificial insemination (AI) program which then strengthened during 1975-1976. In 1960s, the Central Cattle Breeding Station and Dairy Farm (CCBS & DF), Savar was established with Sindhi, Sahiwal and Tharparkar breed cattle to upgrade the native cattle. Later in 1973, some Holstein-Friesian and Jersey bulls were imported from Australia which was used for semen production for upgrading the local cattle. The AI service was then extended throughout Bangladesh for cattle development in 1975. A survey of homestead dairy cattle rearing status showed that highest percentage of rural farmers rearing deshi cows (90.0%) in comparison to Holstein-Friesian (5.80%), Red Sindhi cross (1.9%) and Jersey cross (1.9%) cows in Chapai Nawabgonj district.<sup>31</sup> Dairy farmers' views on the rearing of improved variety of cattle have been described.<sup>60</sup> Productive and reproductive performances (potentialities) of the different crossbred have been reported to be varied.<sup>61</sup>

## Cattle production, management and dairy products

Table 1. Distribution pattern of different available cattle genetic resources in Bangladesh <sup>13,62,63</sup>		
SN Cattle breed & variety	Geographical distribution	Agro-ecological zone/region
1 Non-descriptive deshi	Throughout Bangladesh	All agro-ecological (30) zones
2 Pabna variety	Sirajgonj and Pabna district	Active Brahmaputra and Jamuna flood plain
3 Munshigonj variety	Munshigonj an Manikgonj district	Young Brahmaputra and Jamuna flood plain
4 North Bengal Grey	Northern region (Rajshahi division)	Tista meander flood plain& lowers atria basin
5 Red Chittagong cattle	Chittagong district & CTG Hill tract	Chittagong coastal plain

### Morphometric measurement (MM) of native cattle

The MM of animals is usually conducted for the assessment of carcass quality as well as to characterize breeds of animals. Eight different MM of cattle have been described (Table 2) which include: ① Wither height- vertical distance between the fetlock and the point of wither, ② Hip height- vertical distance between the fetlock and the point of hip bone, ③ Body length - distance between points of shoulder to pin bone, ④ Chest diameter - diameter surrounding the heart girth, ⑤ Chest width measures as the broadest portion of the chest, ⑥ Hip width - distance between two hip bones, ⑦ Thurl width - distance between pin bone to hip bone and ⑧ Rump length - distance between parts of base of tail to hip bone.<sup>35</sup>

Table 2. Body measurement of different varieties and types of adult cattle in Bangladesh					
SN Measurement (cm)	Types	Variety of cattle (Mean ± SE)			
		NDD <sup>33</sup>	RCC <sup>11,35*,43,64</sup>	NBG <sup>14</sup>	PV <sup>65</sup>
① Wither height	Bull	-	125.00 ± 0.87	92.88 ± 2.35	-
	Cow	-	107.71 ± 0.93	93.91 ± 1.13	-
	Overall	100.32 ± 7.79	112.21 ± 0.56 *	-	118.21 ± 3.25
② Hip height	Bull	-	-	-	-
	Cow	-	-	-	-
	Overall	-	109.82 ± 0.49*	-	-
③ Body length	Bull	-	134.00 ± 1.63	99.64 ± 3.48	164.39 ± 2.36
	Cow	-	114.38 ± 1.56	105.16 ± 1.21	-
	Overall	105.78 ± 5.36	110.60 ± 0.45*	-	-
④ Chest diameter/ hearth girth	Bull	-	168.00 ± 1.67	122.23 ± 4.67	-
	Cow	-	139.85 ± 1.63	126.95 ± 1.53	-
	Overall	129.26 ± 6.12	137.22 ± 0.48*	-	147.56 ± 1.70
⑤ Chest width	Bull	-	-	-	-
	Cow	-	-	-	-
	Overall	-	28.82 ± 0.45*	-	-
⑥ Hip width	Bull	-	-	-	-
	Cow	-	-	-	-
	Overall	-	30.69 ± 0.50*	-	-
⑦ Thurl width	Bull	-	-	-	-
	Cow	-	-	-	-
	Overall	-	37.95 ± 0.48*	-	-
⑧ Rump length	Bull	-	-	-	-
	Cow	-	-	-	-
	Overall	-	33.26 ± 0.49*	-	-
NDD = Non-descriptive deshi		RCC = Red Chittagong cattle	NBG = North Bengal Grey	PV = Pabna variety	
* >66 months of age cattle					

## **Draught cattle**

There are three main sources of power used in agriculture: human, mechanical and animal and all have contributed a great deal too human civilization worldwide. Developed world has already converted animal power to mechanical power in the agricultural production. In developing world including Bangladesh, the use of mechanical power in agriculture has increased but the draught animal power (DAP) remains as an important source power in rural agriculture due to small holdings and hill agriculture.<sup>4</sup> All ploughs in Bangladesh require two animals and two bullocks can plough one acre in 2.75 at 6 hours each day. It has been reported that some cows are used for draught purposes, despite problems with fertility and health complications, which result in lower milk production and fewer calving per lifetime.<sup>4</sup> In India, the energy for sloughing two-thirds of the cultivated area comes from animal power and 60 million working animals are saving fossil fuel worth Rs 60 billion annually<sup>66</sup> but similar research report have not been made in Bangladesh (Table 3). In recent decade there has been a trend towards replacing draught animals with mechanization but their status has not been evaluated in Bangladesh (Table 3).

Table 3. Research findings on draught animals in Bangladesh			
Year	Research objectives	Major findings	Reference
1980	To assess the draught power and mechanization	Draught power shortage and suggested for mechanization about 40-50% cows have used as draught animals	3
1984	To assess the performance of draught animal in land preparation	Total time required for complete preparation of an acre of land has been reported to be 60 to 63 hours	67
1985	To assess the single animal ploughing	Cows have been used as a potential single animal ploughing with long term negative effect on fertility	68
1987	To detect the status of DAP	Reported shortage of DAP in Bangladesh	69
1987	To analyze the factors of harassing draught cattle	Good type of harness and anticipated performances of draught cattle have been reported.	70
1990	To detect the types of cattle used in DAP in Pabna	The great majority of the bullocks and the bulls are used as draught animals. More than 80% native cows also have to work compared with only half the PMC.	65
1990	To identify draught power situation and its interaction cropping systems	Results showed that 49% farmers used bullock and 21% farmers used cows as draught animals for land preparation	71
1991	To analyses some farm assets	Shortage of draught animals and cows used for draught purposes.	72
992	To review the draught animal power (DAP) in Bangladesh	Of the 23 million cattle, 11 million are used as draught animals and 25% farmers used cows as DA	73
1992	To detect the relationship between daft animal ownership and land holdings	The draught animal ownership has been reported to be positively correlated with the size of the cultivated land holdings	74

Table 3: Continued

1992	To estimate the economics of single animal ploughing	The benefit/cost ratio has been reported to be higher with single animal ploughing	75
1992	To detect the factors of adopting single animal ploughing	Shortage of draught animal has been reported to be main factor to single animal for ploughing crop land	76
1992	To detect the effect of single and double animal ploughing	Adaptation of SAP with buffaloes and healthier cattle has been suggested to overcome the shortage DAP	77
1993	To assess single animal ploughing in tillage operations	In shortage of DAP, SAP has been suggested in tillage operation	78
1992	Utilization pattern of DAP and cow dung	The utilization pattern of DAP and cow dung have reported not similar among the four regions in Bangladesh.	79
1996	To detect the relationship between draught cattle ownership and land size	Land owner farmers had draught cattle than the landless farmers with positive correlation between land size and number of bullocks	80
1996	To study the feeding practice	Feeding practices of draught animals have been evaluated at village levels	81,82
1997	To study the draught cattle management system	Draught cattle management system at farmers levels with thatched and tin shed house and house-crop-draught cattle have been described.	83
2000	To detect cattle as a source of draught power	Cattle has been reported to be the major animals used as draught animals in Bangladesh.	84
2009	To detect the extent of use cow as draught animals	Reported that cows have been used for cultivation (36.36%), threshing (24.06%), crushing (4.81%), transportation (4.81%) and milking (29.94%) in the nine investigated districts.	4
DAP = Draught animal power      SAP = Single animal ploughing      81 & 82 = Same titles			

### Live cattle body weight measurement

Live body weight of livestock species especially cattle is the basis for determining ration amount and supplement, trait to evaluate breeding value, to decide the slaughter weight, to detect the correct dose of drugs and fundamental importance for research works. There are different live weight measurement techniques are employed in animals, some of which are Weighbridge, Weigh tape, Rondo tape, Schaeffer's formula, Agarwal's formula and calculator method. Weighbridge is the standard calibrated weighing scale which provides accurate body weight but less preferred by dairy producers because it is cumbersome, time consuming, costly and stress full to the animals. However, it can be used as a reference value to compare for other techniques. Evaluation of the techniques showed that Schaeffer's formula is the most reliable of all these techniques to estimate live weight of cattle.<sup>85</sup>

### **Schaeffer's formula to detect BW in cattle**

The equation is used for calculating live weight;  $W = (L \times G^2 / 300)$ , where W is body weight in lbs, L is the length of the animal from point of shoulder to pin bone in inches and G is the chest girth of the animal in inches. The final weight can be converted into kg by  $[1 = 0.453592]$ . Prediction of live weight of cattle fitted regression lines<sup>86</sup> and prediction of live weight for Brahman crossbred cattle using linear body measurement<sup>87</sup> have been reported from Bangladesh.

### **Feeds and feeding practices of cattle**

Cattle is one of the important ruminant animals that convert large quantities of pasture forage, harvested roughage and by-product feeds as well as non-protein nitrogen (e.g. urea) into high quality meat and milk for human consumption. Due to lack of pasture land in Bangladesh, most of the cattle are mainly reared by the smallholder rural farmers and their animals are maintained on crop residues and other agricultural by-products. However, the available animal feed resources in Bangladesh traditionally are grouped into four categories which include ① Forages including grasses and tree leaves, ② Crop residues e.g. rice and wheat straw, ③ Agro-industrial by-products e.g. concentrate and ④ Non-conventional feed resources. Different reports indicate that there is a wide ranging deficit of all these categories of feed resources based on the daily requirement of the animals in Bangladesh. The feeding system of ruminant animals practiced in Bangladesh can be categorized into three which include ① Traditional feeding system, ② Feeding system in the milk pocket areas and ③ Feeding in farming condition.

#### **① Traditional feeding system**

Three categories of feed sources e.g. dry feeds, green feeds and concentrates are usually supplied to the ruminant animals. The dry feeds include paddy, wheat and rice straws and dry grasses. The green feeds include road side grasses, weeds, natural vegetation of homestead, forest grass, tree leaves, aquatic weeds and cultivated forages like Napier, German, guinea and maize fodders, grazing or tethering fallow or harvested land and vegetable wastes. Concentrates are seldom fed to the animals which are usually consisted of rice polish, wheat bran and oil cakes. The traditional feeding system for smallholder dairy cattle is based on the use of rice straw, natural grasses supplemented with a little or no concentrates.<sup>30</sup>

#### **② Feeding system in the milk pocket areas**

Mostly the Milk vita operated regions especially Bhaghabarighat, Sirajgonj, Takerhat and Faridpur are considered milk pocket of Bangladesh and during the winter season especially in the Sirajgonj and Pabna bathan areas, mostly the dairy cows are grazed on developed pasture mainly composed of matikalai, mug beans, chickling vetch and Bermuda grass and varieties of natural weeds. During rainy season and flooded areas, animals are kept in the permanent animal shed and allowed to stall-feeding mainly with rice straw, water hyacinth and excess amount of poor quality by-products such as rice polish, wheat bran and oil cakes and occasionally fed with Napier grasses grown in the high land.<sup>88</sup>

#### **③ Feeding in farming condition**

Dairy cattle of the organized government and non-government dairy farms are usually maintained by feeding both roughage and concentrates. Fodder crops are grown in the farming areas and concentrate are purchased from local market for feeding these animals.

### **Challenges in feeding rice straw**

Rice straw is a major agro-residue feed which satisfies 90% of the roughage needs of large ruminants in Bangladesh<sup>30</sup> but feeding only rice straw does not provide adequate nutrients to the cattle even for maintenance due to low nutritional values (low protein content and poor digestibility) with highly lignified material containing high concentration of anti-nutrition factors like lignin, silicates and oxalates.<sup>89,90</sup>

Paddy straw contains 25 to 45% cellulose, 25 to 30% hemi-cellulose and 10 to 15% lignin with low nitrogen, vitamins, minerals and high quantities of silica which hinder the nutrient availability to rumen microbes and eventually limits the necessary nutrients uptake for a satisfactory performance of the animals.<sup>90</sup> The presence of anti-nutritional factors like silicates and oxalates in rice straw with low nutritive value, poor palatability and limited ruminal degradation render paddy straw as non-maintenance type of fodder, so it cannot support nutrient requirement of the animals when fed alone.

The cellulase, hemicellulase and ligninase are required to break down the cellulose, hemicellulose and lignin predominantly present in the cell wall of the rice straw. However, the cellulase and hemicellulase are produced by rumen microorganisms but lignin cannot be breaking down in the rumen due to lack of ligninase. Rice straw has a very high silica content (5 to 15%) which is indigestible phenolic substance that also decreases digestibility of the feed. This high concentration of silica reduces the palatability and the degradability of rice straw in the rumen due to its direct action in preventing colonization by ruminal microorganisms.

The crude protein of 3.0 to 4.7% on a DM basis in rice straw requires protein supplementation to meet the nutritional requirements of most cattle. The high oxalates in rice straw decrease the absorption of calcium. Since rice straw does not contain enough sugars, amino acids and minerals for efficient microbial growth, feeding ruminants with only rice straw without any supplementation of other required nutrient sources will result in poor performance of the animals. There are technologies that have been developed to increase the nutritive value, nutrient digestibility and utilization of rice straw, such as physical processing, pre-treatment using chemicals and /or biological treatment.

① **Physical treatment-** grinding, soaking, chopping or pelleting to reduce the particle size or can be treated with steaming pressure and gamma irradiation. Physical treatment of rice straw aims to improve the palatability and increase intake as well as improve the potential digestibility of ruminants. Soaking straw overnight in water which brings softness between the lignin and cellulose component which promotes higher intake of the animal as well as nutrients digestibility. Grinding, chopping or pelleting has beneficial effects in breaking down the cell wall contents of rice straw which reduce the particle size of the straw and the retention time or passage rate of the ingested treated straw that causes negative effect on decreasing the nutrients digestibility of straw because of the less time exposure of the feed materials for rumination and for microbial fermentation in the rumen.<sup>91</sup> Many of these treatments are not practical for use on small-scale farms, as they require machines or industrial processing.

② **Chemical treatment-** most commonly used chemicals in treating rice straw to improve its palatability, intake and digestibility are sodium hydroxide (NaOH), ammonia and urea. The mode of action of these chemicals is to break the links between the lignin-cellulose structures of

the straw which are sensitive under alkaline or acid conditions. Chemical treatments appear to be the most practical for use at farmer's level, the chemicals are relatively cheap and the procedures to use them are relatively simple but safety precautions are needed for their use as these chemicals themselves are not harmless.

③ **Physico-chemical treatment-** NaOH / pelleting, urea / pelleting, lime / pelleting, chemical / steam, NaOH / temperature.

④ **Biological treatment-** white rot fungi, ensilage with agro-industrial by-products or fortification with proteins, greens or enzymes, probiotics and herb. Among these methods, biological treatment is a much favourable option and is believed to be more environmental friendly and safer.<sup>90</sup> Suitable treatment techniques in combination with nutrient supplementation could result in improved utilization of rice straw with better benefits.

On a straw diet, supplementation of small amount of green grasses is often recommended for optimization of rumen environment or even to meet the maintenance requirement of animals. Dairy farmers are recommended to feed 1.0 kg concentrate for 2 to 3 kg of milk yield and the concentrate feed contain rice polish, wheat bran and oil cakes under local conditions.<sup>30</sup>

Bangladesh has mainly two types of dairy cattle, cross-bred and indigenous dairy cattle. The cross-bred cows are usually stall fed while the native cows generally allowed for grazing in day time and fed rice straw *ad libitum* basis. The grass supplied to the cross-bred cows composed of roadside grass, on-farm fodder, weeds of crop fields, aquatic weeds, tree leaves and other browse which varies from season to season. Local dairy cows are supplied to a maximum of 1.0 kg concentrate daily whereas the cross-bred cows are supplied with 2 to 3 times higher than local cows and composed of rice polish, wheat bran, bran of legumes and oil cakes.<sup>92,93</sup>

## **Research on feeds and fodders**

Approximately 68.0% of the farmers involved in crop production and 6.5% involved in livestock rearing in Bangladesh.<sup>94</sup> Livestock farming is crucially important for provision of animal-based food products for the population and as a source of income for mainly rural smallholder farmers in low income countries including Bangladesh. Recently the demand of livestock products has increased greatly due to increased human population and economic growth in Bangladesh. However, the main constraints to livestock development in Bangladesh are the scarcity of quality and quantity of feed supply (88.1%) and diseases.<sup>62</sup>

Large ruminants are mainly fed on low quality roughages including natural grazing and agro-industrial by-products like cereal straw, sugarcane feed by-products and other similar products in developing countries including Bangladesh. The smallholder cattle farmers are usually supplied with green grasses mostly grown on fallow lands, crop field boundaries, embankments and side of roads. These feeds are deficient in protein, energy, minerals and vitamins. Sometimes seasonal influence also deteriorates the grazing and browsing that cause to decline lactation unless supplements are offered. Addition of foliage from tree leaves and supplementation with seed meals, urea-molasses multi-nutrient blocks are used to improve the utilization of low quality roughages mainly through the supply of nitrogen to the rumen microbes. Cereal milling by-products, grains and oil cakes are the three major types of ingredients constitute concentrate feed

and the total demand is met only 19.4% in Bangladesh.<sup>95</sup> However, an average 56.2% deficit of roughage DM and 79.6% of concentrate DM results in a very poor plane of nutrition for farm animals in Bangladesh.<sup>95</sup> There is a requirement of 70 million metric tons of green grasses for cattle feed per year but produced only 24 million metric tons. Thus, there is about 60% deficit of animal fodder feed which hampering the livestock development in Bangladesh.<sup>96</sup>

## Fodder production

Fodder is any agricultural foodstuff used specially to feed domesticated livestock. Fodder crops are crops that are cultivated primarily for animal feed. Natural grasslands and pastures are included whether they are cultivated or not. There is a lack of pasture land and huge shortage of green fodder to feed large ruminants in Bangladesh. In 1960 a fodder crop, namely pangola grass (*Digitaria eriantha*) was imported from USA and propagated in a limited area of the then East Pakistan and proved to be high yielding fodder crop suited for local condition. However, the land scarcity, lack of extension services to encourage farmers for fodder cultivation and absence of fodder feed bank have been considered as the main reasons for green fodder shortage in Bangladesh. Recently interest has been grown among the scientists to provide livestock farmers with a suitable variety of fodder crop which could be cultivated abundantly and preserved as hay as well as silage to feed the animals during scarcity period. In addition to different varieties of fodder experimentally cultivated in Bangladesh and even hydroponic fodder has also been tried under experimental condition (Table 4).

Table 4. Research findings on fodder production and fertilizer used in Bangladesh				
Year	Fodder grass cultivated	Fertilizer used (@ kg / ha)	Results (Total harvested /DM produced)	Reference No.
1968	Pangola grass	N + P + K fertilizers	Reported some mineral composition of the cultivated fodder	97
1972	Sorghum	NPK 200/Varity	Honey sorgo (V-4) produced highest fodder yield (119339 kg/ha)	98
1972	Para grass	Urea 0, 30,60 lb/ acre land	DM yield 4380.0, 4894.5 and 6958 lb. with 58.87% increased with used / acre group.	99
1974	Pangola grass (PG)	3 rates of N & P, 2 rates potash	N & P application has increased yield significantly but little effect with potash	100
1975	Para grass	Urea 0,34, 68 ; TSP 0,34, 68 & MP 0, 34	The N and P application has progressively and significantly increased the grass yield at all stages of cutting.	101
1975	German grass	Urea 0, 22,45 & 67	Total yield of forages / ha on both PG & DM basis increased progressively & significantly with the increase in fertilizer level.	102
1975	Pangola grass	TSP 0, 30 & 60	TSP fertilizer progressively increased total yield of PG and DM with increased level of TSP application	103
1986	Different fodder -		Potential crop mixture for fodder production has been described.	104
1986	Tama Rye grass	Application of mefluidide and PP-333	Mefluidide has reported more effective than PP-333 on growth of the grass	105
1987	German grass	NPK 10,20,40; MN 2,4,8 & Mo 2, 4	Highest yield (17 kg/plot) & highest protein content (17.62%) reported with NPK, Mo1 & Mn2.	106

1988	Maize forage	Urea 0, 21, 42, 63	Urea @ 63kg / ha resulted in significantly higher yield of fodder (41.03 MT/ha) at 7 weeks	107
1990	Wheat straw	Phosphorus 60, Sulfur 30	Optimum doses for producing better quality of wheat straw	108
1990	Khaki Bhutto	Urea 50, 100, 150	Highest green forage & nutrient yield with 100 kg urea/ ha.	109
1992	Cowpea forage	Urea 20 + Rhizobium 63	Significantly higher values for ME & NE concentration for lactation	110
1992	Maize forage	Plant thinning & leaf removal	The highest total green stover yield 15.84 ton/ha & 17.85 ton / hac during 1989-90 and 1990-1991, respectively	111
1992	Mixed fodder	To estimate DM and CP of single & mixed fodder	Intercropping of leucaena with cowpea and sun hemp resulted an advantage of more biomass/ nutrients compared to single crop.	112
1993	20 species of fodder crops	Not used any fertilizers	Highest yield reported in Napier-17 (17.81/ ton/ha), followed by Napier-bazra (16.54 ton/ha), Splendida (14.32 ton/ha), Napier-Pusha (13.42 ton/ha) & Pospalum (13.04 ton/ha) in terms of DM.	113
1993	Dal grass	Urea 0, 45,60, 80, 100	Total DM yield/acre/yr increased from 13.4 ton at zero N to 18.4 ton at 60 kg N/acre which was optimum for highest DM & CP.	114
1993	Maize forage	NPK 30-3-15	Cumulative yield of winter (40,60 &80) fodder higher in dibbled plot (9.93 ton/ha) than transplanted plot (7.26 ton/ha)	115
1993	Kent, Swan, Barseem & Oat-barseem	Urea 20 for oat & 100 kg for barseem plots	Higher bio-mass in kent (30.8-42.3 t/ha) variety than swan (21.5 to 39.0), barseem (12.3-21.5) and oat-barseem (32-42.5 t/ha)	116
1993	Maize forage	-	Dibbling of Savar-1 variety maize in rows at 50 cm apart with a seed rate of 40 kg/ha & NPK 15/5-3-15 kg/ha produced optimum fresh yield with CP 8.12%.	117
1994	Oat forage	-	CP contained declined with advancing maturity which have reported as 16.58%,10.64% & 8.75% at 50, 65 & 80 days, respectively	118
1994	Sorghum	-	Production as inter has been reported highly feasible without affecting highly feasible without affecting the grain yield of rice	119
1994	Maize with Khesari	Urea 0, 30, 45 & 60	Highest seed rate with highest urea resulted peak yield (65.35t/ha) & lowest seed rate with lowest urea resulted lowest yield (38.49 t/ha).	120
1994	Maize + Cow pea mixed	-	Green grass yield (28.5 t/h) has reported maximum in T2 (75% maize + 25% cowpea) group that mixed cropping has encouraged.	121
1994	Sun hemp	Composition, digestibilityME	ME contents has reported to be significantly reduced with the increased the age of plant	122
1995	Oat forage	-	The stage of plant growth had a marked effect on the chemical composition, OM digestibility and ME content	123
1995	Maize forage	Urea 0, 50, 75, 100	Application of 100kg N/ha resulted significantly higher yield of both fodder and DM	124
1996	Oat & Maize	Urea 0, 50, 100	Higher yield of oat forage (61.5 vs. 48.9 t/h) and CP (1.3 vs 0.8) compared to maize. Nutrient yield and CP content reported better in oat but higher digestibility and energy content better in maize.	125

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1996	Oat fodder	Urea 0, 25, 50, 75, 100, 150	Oat fodder harvested at 57 days of age through application of 150 kg N/ha reported superior for both green and dry fodder, whereas 100 kg /ha tended to be superior in respect of digestibility of nutrients as well as nutritive value.	126
1996	Native grasses	Urea +	Yield of native grasses has increased with urea application but not consistent with N- rates	127
1996	Sun hemp forages	Rhizobium+ TSP 45, 60,75	Suggested that the Sun hemp forage may be cultivated for feeding ruminants as a good source of nutrients using 60kg TPS / ha.	128
1996	Seasonal & perennial fodders	Cost of producing fodder	Cost of production of seasonal (maize, jowar, cowpea, oat) & perennial (para, napier) fodders have been analyzed. Highest cost for jowar (Tk. 20944.18/ha) and lowest for para (Tk. 10349.86/ha). Highest cost for maize (Tk. 0.66/kg) and lowest cost for oat (Tk. 24/kg) fodders	129
1996	Native grasses	Chemical composition (g/100g DM)	Certain naturally growing native grasses like durba, kanaibashi, kalimona, heicha available during dry and wet seasons can effectively be used as a good source of nutrients for feeding ruminants either as sole feed or in combination with dried roughage	130
1997	Oat fodder	-	Highest yield and DM reported when 1 <sup>st</sup> cut at 40 days after sowing and statistically similar with 2 <sup>nd</sup> cut or single cut at 50% flowering	131
1997	Maize fodder	Urea 120	Higher maize fodder yield has been reported with the application of 120kg N/ha	132
1997	Maize fodder	-	Practice of thinning plants and removing leaves at different growth stages provided a profitable & acceptable level of grain and fodder	133
1998	Intercrop-ping	-	Intercropping of maize with legume forages didnot affect the yield of main maize crop. Nutritionally maize + khesari intercropping showed best results.	134
1999	Native grasses	Urea +	Urea and cow-dung has increased 28.2% CP content but decreased 19.5 of DM. The naturally grown grass species have proved high quality which further could be improved by using N-fertilizer.	135
1999	Native grasses	-	About 20, 11 and 12 native grass species have been identified in fallow land, rice crop land and other crop land in the district of Noagaon, respectively.	136
2000	Triticale	Urea 120	Higher fodder and grain yield of triticale have been reported with 120kg N / ha land	137
2001	Oat and Maize	-	Oat forage has been reported superior than maize forage in relation to CP yield and nutrient digestibility as well as nutrient value.	138
2001	Maize, Khesari, Sun hemp, Maticoli	Urea 100	All forages harvested at the pre-flowering stage -50 days. Application of urea showed significant positive effect on GG, DM, OM and CP yields of maize forage. Maize + Khesari production suggested.	139
2001	Napier, Gaba, & Para grass	-	Napier (29.9) and Gaba grass (37.6) resulted highest biomas yields (t/ha/harvest) and lowest in Para (20.5) in the hill slope of the CTG	140
2002	Roadside grass	Yield & nutritive value of roadside grasses	<i>Phaseolus mungo</i> has been reported to be the best for yield, nutritive value and adaptability	141

2003	Napier grasses	-	Five varieties of Napier grasses (Arusha, Hybrid, Pusha, N-17 and Bazra) have been evaluated. Napier Pusha contained the highest CP (9.0%) and lowest in hybrid (7.0%).	142
2004	Zamboo fodder	Compost & farm-yard manure	Zamboo grass harvested at 60 days of age of using 14 ton compost /ha resulted better for biomass (30.17 vs 29.0) and CP (34.0 vs 8.97 g / 100g) content in comparison to used farmyard manure	143
2005	Cowpea fodder	Rhizobium + Urea	Application of 50% urea + 1000 kg cow dung at the time of land preparation and 50% urea at 35 days of plant age resulted highest biomass & CP. Treatment of the cowpea seed with Rhizobium inoculum and apply fertilizer grade urea @ 25kg N/ha resulted highest nutritive values at 40 days.	144,145
2005	Dal grass	Urea/feces/droppings/Control	Significantly highest biomass (33.3 MT/ha), DM (7.6 MT/ha) and OM (7.0 MT) yields have been reported with urea than other groups	146
2005	Maize fodder	Urea 100 & 200	Resulted higher yield of forage estimated as GG, DM, OM and CP	147
2005	Oat forage	Urea 0, 55, 110 + TSP 0, 10	Highest yield of oat forage has been reported with 110 kg urea and 10kg TSP/ha harvested at 80 days after sowing	148
2005	Oat forage	Urea 0, 55, 110 + TSP 0, 10	Optimum nutritive value and macro-minerals with 110 kg urea and 10kg TSP/ha harvested at 80 days after sowing have been reported.	149
2007	Napier grass	Urea 120 + TSP 20	Reported optimum yield and nutritive value of Napier fodder	150
2008	Maize fodder	DS 0,10,12,14	Maize fodder cultivated through the application of 12 ton DS/ha resulted higher yield and nutrient content	151
2008	Maize fodder	Effect of cattle slurry	Application of 12 tons cattle slurry/ha resulted optimal production of biomass & nutrient content	152
2008	Triticale fodder	Detect the potentiality in nutrition	Triticale is a crop with good potential to produce quality fodder and grain for small scale farmers	153
2008	Triticale fodder	Evaluation of dual purpose fodder	Suggested to produce WRF-7 dual purpose triticale fodder for cattle and feed for poultry	154
2009	Jumbo, Napier & Mustard	To evaluate the economic profitability of fodders	Comparative economic profitability of Jumbo, Napier and Mustard-BB29 T Aman cropping pattern have been evaluated.	155
2010	Gama, Oat & Sorghum	-	Highest fresh yield recorded with gamma (45.06 MT/ha) than oat (17.1 MT/ha) and sorghum (38.87 MT/ha) forages but sorghum reported better than oat and gamma in terms of nutrition	156
2010	Cowpea fodder	Urea 0,15, 25,30	Application of N fertilizer @ 25 kg /ha resulted 96.25 cm plant height, significantly increased the GG, DM, OM and CP	157
2010	Triticale fodder	Cow dung	Effect of cow dung on biomass yield and nutrient composition of triticale fodder have been reported	158
2010	Sorghum fodder	TSP 0,40,80,120	Application of TSP 80kg/ha resulted highest plant height (160 cm) at 60 day, yield GG 25.58 MT/ha and DM 4.0 MT/ha at 66 days	159
2010	Maize fodder	Biogas slurry as a N source	Application of 70 kg of biomass slurry N/ha improved the production of biomass & nutrient	160

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2012	Triticale fodder	-	Out of 10 varieties of triticale fodder, TYT-03 have been reported to be potential variety for its higher CP yield	161
2012	Para, German & Dhal fodders	-	Comparison of the nutritive values of the three fodders, of which German grass showed the best result in respect of nutritive value	162
2013	Para, German and Dhal fodders	Organic + Chemical fertilizers	All the three fodders reported suitable for animal feeding but German fodder showed significantly higher in CP and OM with result in respect of biomass production	163
2013	Struvite compost	Other fertilizers	Comparison of struvite compost with other fertilizers on maize fodder production recorded	164
2014	Jumbo fodder	Urea 0,50,100,150 TSP 0,50,60,70 Manure 10 ton/ha	Urea 100kg/ha plus TSP 60kg/ha along with manure have been suggested to use for highest production of Jumbo fodder (55.22 ton/ha) and its nutritive values	165
2015	Five single & 4 mixed fodders	-	Benefit cost ratio (BCR) of Khesari + Napier dwarf early cropping method has reported to be 1.73 which was higher than other cropping methods, which has suggested for cultivation in the bathan land.	166
2015	Para grass	Pangasius pond water	Higher level of lipid and protein content of para grass have been reported which has a stimulatory factor to dairy cattle production	167
2015	BLRI-Napier-4	Fertilizer*/ Biogas slurry/ Broiler litter/ Layer litter	Highest biomass yield (t/ha) has been reported with biogas slurry (26.80), followed by fertilizer (26.56), broiler litter (22.34) and layer litter (22.34) and layer litter (22.20). Higher DM yield (t/ha) with biogas slurry (3.94) and lowest with layer litter (3.13) and suggested to use slurry.	168
2015	Jumbo grass	Different levels of N & P fertilizers	Reported that Jumbo grass can be cultivated with the application of 80 kg N/ha and 10kg P/hac for maximum production	169
2016	Napier, Splendida, Andropogon	Fodder cultivation in fallow lands	Napier showed highest biomass yield and growth parameters, whereas Splendida has reported in between Napier and Andropogon.	170
2016	Hydroponic fodder	Production & chemical analysis	Maize and wheat seeds have been cultivated as hydroponic fodder with high production and nutritive values in tray condition	171
2016	Napier fodder	Effects of organic manure on production	The production performance and nutritive values of different napier fodder have been evaluated.	172
2017	German & Napier	Floating bed fodder	Napier grass could not survived but German grass produced 7.7-8.6 ton/acre in floating bed system of cultivation.	173
2017	Napier fodder	Survey of farmers	Biomass yield estimated to be 207 ton/ha/year with BCR (Benefit cost ratio) 1.92 for producer and 2.01 for producer cum seller	174
2017	Feeds & forages	Survey of farmers coastal region	Seasonal availability of feeds and forage, utilization and management practices for livestock in coastal areas have been reported.	175
2017	Native grasses	Survey of native grasses	About 48 different native green grasses have been identified in different agro-ecological zones, amongst which dubra, badla, kawn, shama, khesari, gamma, ura, gobra and maskkalai are commonly available	176
2017	Rice vs Jumbo Napier	Comparative profitability between fodder and rice production	Farmers earned more profit from fodder than rice (Tk.) production. Significantly higher income generation has suggested with fodder than rice cultivation in the Milk-shed area of Shahjadpur	177

2017	Napier fodder	To assess the economics of fodder production for dairy farms	Fodder production along with dairy cattle rearing has been reported highly profitable. Higher profit has been reported with fodder crop cultivation in the same land.	178
2018	Napier-4 fodder	Production on loamy & sandy soils at 3 <sup>rd</sup> cutting	BLRI developed Napier-4 showed better performance in loamy than sandy soil at 3 <sup>rd</sup> cutting	179

NPK= Nitrogen (urea), Phosphorus (TSP) and K (muriate of potash) Mn = Manganese sulfate Mo = Molybdic acid  
 90S = Summer only +@ 25g/ kg seed Intercropping = Khesari, Cowpea and Berseem with maize  
 DS = Dried slurry (ton / ha) Fertilizer\* = Not available in the main text

There are approximately 30 species and varieties of fodder have been cultivated and evaluated in Bangladesh for feeding large ruminants (Table 4). Highest number of research reports have been published with Maize (n = 17) and Napier (n = 14) forages (Table 4). However, intercropping Maize and Kashari production reported best results,<sup>134,139</sup> Oat forage has reported superior than Maize forage as nutrient values,<sup>138,148</sup> German fodder showed best result in respect of nutrient values in comparison to Para and Dhal grasses,<sup>162,163</sup> moreover, German grass can be produced in floating bed but not Napier grass.<sup>173</sup> In addition, triticale has been reported to be a dual-purpose crop for grain and forage biomass, which is a non-traditional cereal that grows well during the cool and dry rabbi season (November to March) when small-scale dairy farmers face a severe shortage of fodder. Winter has considered as a lean season for the growth of the popular fodder including Napier and Para in Bangladesh. To meet the shortage of green fodder in the rabbi season, triticale can be produced 6-15 t/ha fodder, followed by grain yields that are similar to those from wheat for poultry feed.<sup>137,153,154,161</sup>

### **Cattle nutrition, feeds and feedings**

The research reports on the cattle nutrition, feeds and feeding practices have been reviewed into three sub-headings which include (a) nutrition, feeds and feeding practices, (b) feeding trials on non-dairy cattle and (c) feeding trials in dairy cattle (Tables 5,6,7). A balanced ration should provide protein, energy, minerals and vitamins from dry and green fodders, concentrates, mineral supplements and others in appropriate quantities to enable the animal to perform optimally and remain healthy. Inadequate and imbalance feeding may results in: (a) low milk production than their genetic potential, poor growth and reproduction, (b) shorter lactation length and longer calving intervals, (c) dairy cows more prone to metabolic disorders milk fever, ketosis, (d) slow growth in growing animals and delayed age at first calving, (e) shorter productive life and lower profit to farmers.<sup>180</sup> A software has been developed by NDDDB, India to supply the balance ration of their animals using locally available feed resources<sup>180</sup> that system could be used for the development of cattle industry in Bangladesh.

Year	Research objectives	Major findings	Reference
1965	Use of urea-molasses	Utilization of molasses and urea-molasses as a livestock feed.	181
1968	Nutritive values of four forages	Significantly varied nutritive values of four forages at the different stages of maturity and both the TDN and DOM. Varied within the same species of fodder	182

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1968	Concentrate feeding	High level concentrate feeding practice in dairy and beef cattle	183
1968	Relative values of protein supplement	Meals or cake made from soybean, cotton seed, linseed and guar evaluated as protein supplement in cattle	184
1968	Ration mixed with urea, water or rice gruel	Ration mixed with urea utilized without any harmful effects but water or rice gruel mixed with urea caused toxic effect.	185
1969	To estimate the rumen microbial protein	Methods on quantitative estimation of rumen microbial protein synthesis has been described.	186
1972	Partial replacement of vegetable protein	The effect of partial replacement of vegetable protein by urea nitrogen on CP digestibility by ruminants have been reported	187
1974	Role of N in nutrition	Nitrogen- a limiting factor in animal nutrition	188
1980	Chemical composition of water-hyacinth	The chemical composition of three types of water-hyacinth varied from type to type but leaves found best for feeding	189
1981	Feeding of mixed diet with water hyacinth	Rice straw, water hyacinth and concentrate mixed diet has been reported to be used efficiently in bullock	190
1981	Water-hyacinth as cattle feed	Water-hyacinth ( <i>Eichhonia crassipes</i> ) as cattle feed has been suggested in Bangladesh	191
1982	Supplemented alkali treated rice straw	The supplement of protein (fish meal, rice bran) relatively upgraded in the rumen as an essential supplement to urea-treated rice straw for growing calves	192
1982	Treated and untreated rice straw for calves	Evaluation of 5.0% urea, 4.0% lime, 3.0% caustic soda plus 1.0% lime treated straw showed that the better result reported with urea-treated rice straw.	193
1982	Effect of feeding oil cake on COD of DM and OM in comparison to urea feeding in cattle	The feeding of oil cake as protein nitrogen source, the COD (co-efficient digestibility) of DM and organic matter (OM) have reported to be always higher than obtained with urea mostly due to preferential growth of cellulytic bacteria in the presence of protein nitrogen rather than non-protein nitrogen	194
1982	Physiological factors	Influencing intake and digestion of rice straw by native cattle	195
1983	Nutritive values of Bazra-Napier grass	Results showed that Bazra-Napier grass contained 1.59% protein, DM intake 1.26 kg/100kg bwt, CP intake 207g daily and N retention 21%	196
1986	Effect of feeding urea-molasses treated straw	Utilization of rumen microorganisms and ammonia concentration in the rumen have been reported	197
1987	DM degradability between urea-treated and un-treated wheat straw	The DM degradability of wheat straw has been reported to be increased significantly from 34.96% in untreated to 46.6% in 6% urea-treated wheat straw at 2 liter moisture for 15 days	198
1987	Nylon bag degradability of DM & N in different tree leaves and forages	The highest and lowest CP contents have been reported to be 28.12 and 0.95% in Ipil-ipil and mango leaves respectively. The effective protein degradation at rumen outflow rates have recorded as 2.2, 4.4 and 6.6% per hour in different tree leaves.	199
1987	To detect composition of shoti rhizome	Protein in various soluble fractions and the amino acids composition have been reported.	200
1988	To evaluate the rice straw ensiled with poultry excreta (PE) &/or urea and molasses	The digestibility has increased when rice straw ensiled with 30% PE or 15% PE + 1.5% urea or 10% PE + 1% urea. The highest DM (66.73%) and OM (73.02%) digestibility has been reported with 30% PE than 15% PE + 1.5% urea	201

1988	Production of water-hyacinth in earthen pots	Relationship between the content of nitrogen in water and water-hyacinth and its production has been reported.	202
1989	Proximate composition of tree leaves, vegetables and wastes	Sajna leaves have reported highest CP (24.0%) and moderate CF (16.0%), badha kapi and sheem shak contained highest CP (20.0%) and low CF (8.0%)	203
1989	To investigate the feeds used for feeding animals at flood areas	Farmers used alternative feed items at flood area like deep water weeds, water-hyacinth, banana plant for their adult animals. Rice straw, rice polish and mustard oil cake have also used.	204
1989	To detect the effect of feeding wheat straw treated with cattle urine	Wheat straw treated with cattle urine @ 0.5, 1.0 and 2.0 L/ kg straw and ensiled in mini-silos for 5, 10 and 15 days at 5, 20 and 40 °C. The CP (5.5% to 7.1 and 8.0%) and digestibility (33% to 43 and 45%) increased due to feeding of urine treated straw	205
1989	Water hyacinth based diet	Nitrogen balance study has been reported with water hyacinth based diet	206
1989	Ensiled water hyacinth based diet	The physical and chemical characteristics of the water hyacinth silage have been reported.	207
1991	To investigate the feeds & feeding practices of large ruminants in rural areas	Farmers used dry straw, green straw, green grass, gruel, rice bran, pulse straw, oil cake, water hyacinth as animal feeds. In addition, tree leaves, banana plant, climbing vines used in feed crisis.	208
1991	To investigate the feeds & feeding practices of large ruminants in rural areas	Farmers used rice straw, rice bran, rice gruel, green grass, kitchen waste (vegetables) and salt are the conventional feeds. Molasses, green plan & tree leaves and herbs also used.	209
1991	To investigate the feeds & feeding practices in large ruminants at rural level	Crop residues and by-product used as animal feed of which rice straw accounts nearly 100% feed energy along with rice polish, oil cake, salt and green grass. Only 36% owner urged to grow fodder crops and 64% did not due to lack of land.	210
1991	To identify feed & fodder situation & its impact	Inadequate nutrition are directly related to poor health, low milk yield and low work output	211
1991	To detect potential shrubs and tree fodder	The potential shrubs and tree fodder have been suggested for smallholder livestock production	212
1992	Yield, chemical composition & <i>in-vitro</i> digestibility of groundnut straw	DM yield varied from 0.91 to 1.92 tons/ha and the proximate components of DM varied from 19.86 to 24.20, CP 12.57 to 13.19, CF 31.15 to 33.22, EE 4.14 to 4.72, ash 5.69 to 6.94, NFE 41.98 to 45.07 & OM 93.10 to 94.31% on DM basis	213
1992	To investigate the feeds & feeding practices of large ruminants in rural areas	Conventional feeds- dry straw, green straw, green grass / weeds, water hyacinth, green khesari / kalai, pulse straw, oil cake, rice bran and salt. Crisis period feeds- water hyacinth, green grass, banana tree, jack fruit tree leaves and bamboo leaves.	214
1992	To investigate the feeds & feeding practices of large ruminants in rural areas	Majority of the farmers practiced stall feeding and tethering (38.4%), followed by stall fed (34.3%) and grazing or tethering (17.3%). Also supplied concentrates mixed with water (74.1%), followed by mixed with roughage and water (10.3%) or fed alone (5.6%)	215
1992	Feeding of jiga leaves	Nutritional utilization of jiga leaves in cattle	216
1992	Influence of acacia pod and soybean meal	Ruminal fermentation pattern and serum mineral status in local bull calves have been detected due to influence of Acacia pod and soybean meal	217

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1992	Effect of lime treatment on paddy straw	The effect lime treatment on the chemical composition and digestibility of paddy digestibility of paddy straws have been reported	218
1993	The <i>in vivo</i> digestibility of urea treated rice straw	The NDF or hemicellulose determination of straw treated with either Ca (OH) <sub>2</sub> or mixtures of Ca (OH) <sub>2</sub> and urea not recognized for prediction of digestibility	219
1993	To detect the OM and CP of ensiled sugar cane tops (SCT) mixed with urea and molasses	The SCT chopped at a length of 3 to 5 cm and mixed with 0, 1 and 2% urea and all the three groups mixed with 20% cane molasses, wheat bran and 2% common salt and then ensiled for 246 days. No significant differences for OM but significantly higher CP reported in urea treated SCT	220
1994	Comparative digestive capacity of cattle & buffalo	Buffalo heifers have reported more efficient than cattle heifers with respect to utilization of nutrients (DM, CP) from mixed diet	221
1994	Evaluation of legume forage and rice straw	The effect of legume forage supplements on chemical composition, OM digestibility energy contents of rice straw have been reported	222
1994	To investigate the major constraint to animal production in flood plain area of Patuakhali	Feed shortage is the major constraint to animal production especially during January to February and June to October in the non-saline tidal flood plain area. Farmers are usually keep their animals grazing on road sides, green and tree leaves	223
1994	To detect the urea and moisture level in straw	Reported that the rice straw could be treated at 5% urea with 55% moisture level and ensiled for optimum period of 14 days	224
1995	To detect the possibility to use algae as a substitute for oil cake for growing calves	For the 120 days feeding trial of using unicellular algae as feed for cattle, the estimated net economic loss has been reported as US \$ 5.0/ animal on oil cake while US \$ 14.4 profit/animal on algae	225
1995	To compare the quality of different varieties of rice straw	Higher rates of straw and grain production reported in improved than native of rice. Pasam straw has reported as a best based on chemical composition and energy content.	226
1995	To investigate the seasonal availability of green grasses & their effect in live weight	Higher intake of DM of cattle at bathan during winter due to availability of green forages which corresponds to better LWG whereas due to scarcity of green forages during summer, the daily intake of DM decreased which corresponds to lower LW.	227
1995	To assess the farmers' knowledge & technology on animal feeds & feedings	Limited knowledge of farmers in feeds and feeding and cultivation, storage and processing. Effective extensive program for fodder cultivation within the existing cropping system is required	228
1995	To investigate the availability of livestock feed ingredients	Twenty different livestock feed ingredients have been reported to available in the Pabna Milk shed areas.	229
1995	To investigate the effect of replacement wheat bran by rice polish in growing calves	Significantly higher feed efficiency and LWG have been reported with 100% replacement of wheat bran with rice polish. Rice polish appears to be promising substitute of wheat bran for growing bull calves	230
1995	To evaluate the energy content & digestibility of grasses	The effect of drying temperature and collection procedures of rumen inoculum on digestibility <i>in vitro</i> and ME contents of grasses have been reported.	231
1996	The feedstuffs & composition of concentrate commonly used to fed animals	Straw, green grass, tree leaves and water hyacinth, legumes and sugar cane tops are the major feedstuffs fed by most rural farmers. Composition of concentrates includes rice bran, wheat bran and admixture of different oil cakes.	232
1996	To evaluate the dried duckweeds as a component of a concentrate mixture	The diet has supplied with a concentrate mixture contained duck weeds @ 279 g/kg. Both DM and CP of the duckweeds as a component of a concentrate mixture has been suggested	233

1996	To find out the feasibility of preservation of seasonal wet rice straw with urea	Seasonal wet rice straw mixed with 50 to 70g urea / kg DM and ensiled for 180 days. Such preservation increased the CP contents of straw by 3.6 to 6.4 times than of the dry straw	234
1996	To evaluate the effects and benefits of feeding preserved wet straw with 5% urea in native growing bulls	Of the two groups of growing native bull calves, of which one group fed with dry straw and other group fed with urea preserved straw <i>ad libitum</i> . Fresh and wet rice straw with relatively lower moisture (400-500g H <sub>2</sub> O/ kg straw) have been preserved with 5% urea without polythene or any other cover.	235
1996	To compare the nutritive values between the preserved straw (PS) and dry straw on feeding growing bulls	Results showed that > 96% of the wet straw has been excellently preserved for over 5 months when covered with polythene in heap. The increased of the CP content (95 vs 50g/kg) in urea preserved wet straw and DM degradability. However, feeding of PS resulted nervous disorders due to unknown reasons.	236
1996	To detect RDP values of feedstuffs used in ruminant ration	Large differences of degradability of CP contents among 9 roughages (rice straw 16.7 to sun hemp & Daincha 78.4) and 8 concentrates (auto rice polish 30.9 to sesame oil cake 74.2) have been reported.	237
1997	To detect the existing management and economic status of private dairy farms	Napier, para and maize are the main fodder cultivated by the private dairy farmers. Approximately 42.0% dairy farmers used stall feeding and 58.0% used both grazing and stall feeding of cows.	238
1997	To detect the effect of feeding dried cow-dung (DCD) on growth and nutrient utilization in growing bull calves	Feeding of DCD (0, 250, 400g/kg) mixed with concentrate for 75 days resulted 16.35, 15.5 and 13.66 kg LWG, respectively. However, authors have suggested to use DCD to replace 40% rice bran of the concentrate mixture in bull without any harmful effect	239
1997	Chemical analysis & nutritive values of fruit wastes	The extraction rate of jackfruit, pine-apple and mango wastes have been reported as 50.0%, 25.0% and 20.0% by weight, respectively	240
1998	To determine the comparative rumen degradability of different protein supplements in adult bullock fitted with permanent ruminal cannula	Each experimental animal has supplied a maintenance diet containing straw, green grass, wheat bran and supplemented with either coconut oil cake, til oil cake, or soybean meal. Effective degradability of CP for soybean meal (84.07%) has reported highest than that of til oil cake (78.97%) and coconut oil cake (63.23%).	241
1998	Replacement of til oil cake by dried poultry excreta	Results showed that til oil cake can be replaced by dried poultry excreta in bull calf ration	242
1998	Role of energy in cattle	Energy cycling through cattle to human utility seems in ecological framework	243
1999	To detect the effect of graded levels of mustard oil cake (MOC) supplementation on a urea-molasses-straw based diet on native bulls	The basal diet includes urea-molasses-straw (3:15:82, UMS) ad lib., wheat bran 200g, molasses 200g, oyster shell 40g and common salt 70g daily. Mustard oil cake has supplied at 0, 200, 400 & 800g daily. UMS with MOC up to 800g has reported little or no effect on intake, digestibility, rumen parameters and microbial N yield but slightly increased the N balance.	244
1999	Probability of feeding bi-digestereffluent in bulls	Biodigester effluent has been fed to native bulls but it has been reported to be inferior to mustard oil cake as a supplement for a straw-based diet.	245
1999	Effect of RDP from urea on rumen fermentation in cattle	Results showed that the straw based diet containing 100% RDP reported superior to others RDP levels when urea was used as RDP supplement	246
1999	To evaluate the urease source in ammonia treated straw	The addition of soybean to urea at a ratio of 1 : 1 has been reported to be the most satisfactory urease source for the treatment of urea and wheat straw	247
2000	To investigate the degraded different rumen protein	Fish meal and soybean meals have been reported to be degraded slowly up to 12 hours and thereafter rapidly up to 48 hours of incubation	248

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2001	To find out the major feed-stuffs of cattle during normal and shortage period	The major feedstuffs for livestock has been reported as straw, green grasses, rice bran, wheat bran, oil cake and kitchen wastes. Water hyacinth, banana & jackfruit leaves during shortage period.	249
2002	To find out the availability of feeds and amount intake by large ruminants	Mean intake of different feeds in ruminants (kg/head/day) include straw 2.0 kg, green grass 5.0 kg, tree leaves 0.3 kg, legumes 0.1kg, sugar cane top 0.01kg, rice, bran 0.5kg wheat bran 30g, oil cake 10g and grazing 6.0 hours.	250
2002	To estimate the quantitative availability of acids in the ruminal fluids in cattle	The concentration of PAA (phenylacetic acid) and PPA (phenyl-propionic acid) have been reported in the rumen fluids and seemed to be able to stimulate cellulose digestion in the rumen.	251
2002	To investigate the effects of different levels of RDP on growth and nutrient utilization in native bull calves	The feed intake, digestibility of nutrients (except CP) and liveweight gain have not been significantly improved with the increased level of RDP (rumen degradable protein) level in the diet. The diet containing 6.95g RDP/ MJ ME has suggested to use in cattle.	252
2002	To evaluate the nutritive potential value of different aquatic plants	A wide variability in protein, mineral composition, gas production, microbial protein synthesis, rumen degradable nitrogen and in situ DM and CP degradability have been recorded in duckweed, azolla and water-hyacinth and these have suggested to use supplementary diet to ruminant animals.	253
2003	To detect the level of mycotoxin excretion in milk of cows fed fermented rice straw	Fermentation of rice straw due to dampness reduced its soluble nutrients, <i>in vitro</i> digestibility and degradation of DM and increased effective degradability of CP. Dampness of CP resulted to excrete ingested aflatoxin M1 (0.001-0.006 µg/kg milk) from fermented straw to milk	254
2003	To detect the traditional feeds and feeding practices in large ruminants	The overall consumption of straw, green grass, leaves, legumes, and sugarcane tops have been reported as 1.9, 5.1, 0.3, 0.1 and 0.01kg/head/day respectively Concentrates consisted of rice bran, wheat bran and oil cakes as 0.5, 0.03 and 0.01 kg/head /day respectively.	255
2004	To compare the feed intake, feces outgo, digestibility and LWG in RC & HF cross cows	Feed intake and feces outgo have been reported to be much lower in RCC (4.94 kg / d & 6.16 kg / d) than HF cross cows (6.23 kg/d & 8.26kg/d), respectively. Low feed intake and high digestibility have reported to be the profitable for RCC	256
2004	Effect of OM of digestibility & ME in legume foliage	Results showed that acacia, albizia and sesbania contained higher CP and ME and suggested to use as supplement to ruminants fed low quality forages	257
2006	To improve the nutritive value of rice straw by treating with urea and different sources of urease enzyme	Results showed that the silage made by using 4% urea, 2% molasses, 4% soybean seed meal and 40% Dhaincha leaf with 50% rice straw which has preserved under anaerobic condition for a period of 21 days. The highest CP content (16.42%) has been reported with 40% Dhaincha	258
2007	Effects of the feeds and fodder on milk production	Cattle feed constituted 27-49% rice straw. Napier fodder production has practiced in Sirajonj and Satkhira whereas limited grazing facilities in Sirajonj and CTG	259
2008	To compare the effect of supplement between bone meal and TSP in local cattle	Supplementation of bone meal (1.87 g/kg) and triple super phosphate= TSP (1.10g/kg) in the diet of local cattle resulted in high blood serum P with no difference between them.	260
2008	To evaluate the nutritional quality & preservation status of 4% molasses mixed straw	Addition of 4% molasses and 90 days ensiling of maize straw showed good color, smell, softness, nutritional quality and longer preservation capacity. Suggested that maize stover may be ensiled for 90 days by adding 4% molasses and 20% water.	261
2008	Effects of nitrogen on yield, chemical composition and nutritive value of dal grass	Urea (240kg/ha), cattle manure (25.7 ton/ha), goat manure (13.2 ton/ha), rabbit manure (7.6 ton/ha) and poultry manure (5.9 ton/ha) have been evaluated of which poultry manure has suggested as a source of N fertilizer for dal grass production.	262

2008	Effect of urease sources on proximate composition, NH <sub>3</sub> -N production, energy value of urea ensiled rice straw	Nutritive value of rice straw reported to be improved by adding 5% urea and 5% urease containing plant sources like soybean seed meal, cowpea seed meal and preserved for at least four days under anaerobic condition at 40% moisture level.	263
2008	To assess ensiling rice straw with urea, molasses, soybean meal with aquatic plants	Results showed that the nutritional values of rice straw has been improved by ensiling with supplementation of urea (4%), molasses (2%), soybean meal (4%) and aquatic plants (water hyacinth, azolla and two varieties of duck weeds).	264
2009	Effects of feeding rice straw with wood ash extract (WAE) in growing bull calves	Feeding of rice straw mixed with WAE in growing bull calves have reported to be improved nutritive value and increased digestibility value of rice straw and LWG of animals within 60 days	265
2009	Supplementation of water hyacinth in a rice straw	Wilted water hyacinth ( <i>Eichhornia crassipes</i> ) with rice straw based diet resulted positive effect on intake and growth of beef cattle.	266
2010	To assess the nutritive values of different varieties of rice straw to develop a feeding system for its efficient utilization	The dry matter (DM), organic matter (OM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, Ca and P contents of pajam, nijershal, kabladam, RB 11, BINA5 and BRRI 29 varieties of rice straw have been evaluated of which BRRI 29 has been reported as best straw based on CP, P, OM digestibility and ME content.	267
2012	To detect the status of fodder cultivation at rural levels	Fodder cultivation is limited at 35% dairy farmers and 65% farmers are not usually cultivate fodder due to limited land.	268
2012	To estimate the arsenic level in rice and rice straw in the arsenic contaminated areas	The concentration of arsenic in rice and rice straw has been reported to be 0.235 ± 0.014 ppm and 1.149 ± 0.119 ppm, respectively, which has recorded as higher levels than the maximum permissible level in drinking water (0.05ppm)	269
2012	Effects of different levels of RDP on intake, digestibility and MPS by supplementing MOC on rice-straw based diet	Supplementation of RDP from MOC (mustard oil cake) enhanced the intake, digestibility and microbial protein synthesis which ultimately increased utilization of low-quality feed resources for developing cost-effective feeding systems on a straw-based diet	270
2015	To detect an alternative source of protein by feeding moringa leaves in ruminants	Moringa leaves have been shown to alter favorably ruminal protein fermentation characteristics thus spare protein by a decreased breakdown /deamination of protein/amino acids that functions as of monensin	271
2015	Chemical composition and nutritive value of water hyacinth	100g water hyacinth contains DM (8.7-9.3g), CP (10.1-11.2g), CF (26.1-27.4g, EE (1.1-18g), NFE (47.2-50.2g) and TA (12.3- 12.4g) which indicates that water hyacinth can be used as feed for ruminants especially during scarcity period.	272
2015	To evaluate tree leaves and natural grasses chemically & <i>in vitro</i> gas production	Nutritional variations exist between & among the natural roughages and foliages. Foliages reported as the best and herbs better than natural grasses. Suggested that the potential sources might be considered prior to feeding the animals	273
2016	To determine the biomass yield, morphological characters and nutritive value of high yield napier cultivars	Results showed that the biomass yield in order from BLRI Napier hybrid > BLRI-Napier-4 > Merkeron > Wruk-Wona > Napier-Japan. The 3 <sup>rd</sup> cutting contained more DM compared to 2 <sup>nd</sup> and 21 <sup>st</sup> cuttings. Higher oxalate in BLRI N-4 and higher CP in MarkEron	274
2016	Effect on growth performance and metabolites in cattle fed with rice straw used as bedding for mushroom	About 10% rice straw of control group replaced by the used bedding rice straw of mushroom cultivation which fed to treated group for 60 days. The higher reported in treated than control group of cattle, whereas lower values of total cholesterol, triglyceride, HDL-C and LDL-C reported in treated than	275

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2018	To select best combination of roughage & concentrate based on TMR, better rumen environment & RMF in cattle	The best combination of roughage to concentrate ratio (30:70) has been reported in T5 group (30:70) for better N utilization to achieve maximum performance through proper feeding which might reflect the gross return of cattle production	276
2018	Preparation of ensilage with WRS treated with BGS and ensiled with molasses to increase nutritional and preservation of straw	Among all the treatments, T <sub>2</sub> (5% BGS= Biogas slurry) and T <sub>3</sub> (10% BGS) have been reported acceptable for preparing ensilage. Ensilage of WRS (wet rice straw ) with BGS not only reduced waste disposal and pollution problem but also provide inexpensive feed components for ruminants	277

Table 6. Trials of different feed formulations for the enhancement of growth and body weight in **non-dairy** cattle

Year	Major objectives	Major findings	References
1981	Effect of feeding water hyacinth in bullocks	Rice straw, water hyacinth and concentrate mixed diet has been fed to bullocks efficiently	190
1982	Effect of feeding urine treated rice straw	Performance of cattle fed treated paddy straw with animal urine as a source as a source of ammonia.	278
1984	Voluntary DM intake & feed efficiency	Feed efficiency of Nili-Ravi buffaloes has been reported higher than Red Chittagong cattle	279
1986	To utilize sugar cane bagasse as a partial replacement of rice straw in growing crossbred bull calves	Four groups of crossbred (SL × L) bull calves fed with four different combination of feed ingredients with basal diet straw. No significant differences on live weight gain and feed efficiency in different groups has been reported. However, 50% replacement of straw by bagasse may be recommended for the growing calves.	280
1986	Replacement of straw by sugar cane bagasse	Approximately 50% replacement of rice straw by sugar cane bagasse for feeding to young bulls has been recommended by nylon bag technique.	281
1986	To detect the digestibility of DM and OM of rice straw treated with poultry excreta or urea	Poultry excreta up to 30% has been reported to be superior to urea in increasing the digestibility of straw in cattle. Supplementation of leucaena leaves decreases the digestibility of straw probably due to presence of toxic factors (mimosine) in these leaves.	282
1988	Effect of feeding urea-treated straw on CP level	The CP has reported to be increased significantly from 2.99% in untreated straw to 5.7% with 1 liter moisture level at 6% urea level in 6 days.	283
1988	To detect the effect of DMI from different sources of roughages on LWG in heifers	The initial LW of Sahiwal, Red Sindhi, RCC, SL x L heifers have reported as 211,154, 148 and 166 kg and the daily DMI / 100 kg BW as 2.42, 3.19, 3.36 and 2.98 respectively. The DMI has been reported higher in younger animals of lower BW.	284
1988	To detect the effect in vitro digestibility	Effect of addition <i>Leucaena leucocephala</i> to rice straw ensiled with poultry excreta and/or urea on its <i>in vitro</i> digestibility	285
1989	To compare the LWG, DM intake and feed efficiency of bull calves fed with urea supplemented, urea treated and urine treated rice straw	Significantly higher LWG and feed efficiency have been reported in all the three treated groups, urea supplemented (4.67kg & 25.47), urea treated (7.5 kg & 17.61) and urine treated (7.0kg & 16.27) as compared to untreated control group (2.67 kg 41.38) respectively. However, significantly higher DM intake has been reported in urea-treated group (131.39kg) in compared to urea supplemented (117.3kg), urine treated (113.67kg) and untreated control (108.88kg)	286

1990	To detect the benefit of adding CaOH + urea or NaOH + urea treated ensiled barley straw	CaOH or NaOH with urea treatment of straw, urea hydrolysis has inhibited and nitrogen content has increased compared to control urea alone treatment. No benefit has been reported of adding urea with CaOH or NaOH in ensiled straw.	287
1991	To detect the effect on voluntary intake of dried stover mixed with other feed ingredients	The voluntary intake of maize stover (3kg / bullock) chopped and soaked overnight and mixed with other feed ingredients have been reported higher when mixed with paddy straw (0.75kg/bullock) + mustard oil cake (0.25kg / bullock).	288
1991	To detect the performance of growing cattle fed 1-2% urea water soaked rice straw	Highest LWG has been reported in growing cattle fed with 2% urea soaked rice straw supplemented with rice polish (900g), molasses (100g) and common salt (50g) per head per day. However, 1% urea soaking rice straw has been suggested with supplementary feed.	210
1991	To compare the natural protein supplement with urea-treated rice straw on LWG in calves	Highest daily average LWG has been reported in urea untreated mustard oil cake treated group (302.3g) in comparison to 1% (273g) and 2% (201.6g) urea-treated groups of bull calves. The natural protein (mustard oil cake) supplement has proved better than urea-treated rice straw, however, it is expensive	289
1991	Leucaena alternative to fish meal in lactating cows	Performance of lactating dairy cows has been evaluated by feeding <i>Leucaena leucocephala</i> as an alternative protein supplement to fish meal	290
1993	Effects of feeding urea-treated straw & urea directly in bullocks	The daily LWG, feed efficiency, CP and CF digestibility have been reported to be significantly higher in animals fed with urea- treated rice straw than feeding urea directly to animals for 75 days.	291
1993	To compare the feed values of Napier, Para and German grasses	Crossbred (Sahiwal × Local) calves between 448 and 538 days of age have been used to compare the feed values of these grasses. No significance difference has been reported of feeding these grasses in growing calves	292
1993	To detect the effect of feeding water- hyacinth (WH) in crossbred bull calves	Highest LWG recorded in calves fed with urea-treated rice straw (UTRS) + WH (ILW 50kg & FLW 83kg) in comparison to fed untreated rice straw + green grass (ILW 58kg & FLW 67kg) and fed with UTRS + green grass (ILW 58kg & FLW 77kg). [ILW = initial live weight and FLW = Final live weight]	293
1994	Effect of feeding urea-soaked and urea-ensiled rice straw in bull calves	Considering the labor, tediousness and acceptability to the farmers, treatment of straw by soaking in urea-water has been reported as better than urea-straw ensiling method.	294
1994	To determine the optimum level of urea treated rice straw (UTRS) for heifers	LWG has been reported to be higher with UTRS than urea supplemented straw at all levels but 6% level of UTRS showed best performance on the growth of heifers. About 42.5% higher LWG has been reported with UTRS than control.	295
1994	To detect the growth and LWG performance of local calves by feeding different sources of protein in diets	The diets of growing calves contained UTRS, green grasses and wheat bran as basal feed with either (kg/d) fish meal (0.15), fish meal + Leucaena (0.5) or only Leucaena (1.0). Fish meal showed positive effect on the performance (LWG 160 and 143 vs 101g/d)	296
1994	To detect effects of UMB with straw diet in cows	The UMB supplementation to rice straw diets has clearly altered the eating and rumination behavior in cows.	297
1994	To evaluate the different types of urea-molasses feeding technologies at sustainable level in cattle	Feeding of urea treated straw (UTS), multinutrient blocks (MNB), direct feeding of urea-molasses solution (UMS) and urea mixed straw (UMS) have been evaluated. Farmers who fed UTS and MNB discontinued when supply of input whereas feeding of UMS and UMS continued even after withdrawn of support.	298
1994	Effect of feeding urea/high protein to breeding bulls	Results showed that the excessive quantities of urea in the urine fluid of high protein fed cows may be detrimental to the viability (1994-98) of spermatozoa.	299

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1995	Leucaena alternative to fish meal in calves	Performance of calves has been evaluated by feeding <i>Leucaena leucocephala</i> as an alternative protein supplement to fish meal	300
1995	Influence of feeding urea-treated rice straw with fish meal on dressed carcass weight in bull calves	1.5% urea-treated rice straw fed ad libitum and supplemented with different levels of fish meal (g/day) to the bull calves more than one year old for 120 days. Results showed that there has little effect on dressed carcass weight supplemented more than 50g fish meal in bull calves.	301
1995	Effects of feeding between urea and Til oil cake + fish meal in local bull calves	The 40% of CP of the ration A (Til oil cake + Fish meal) has been replaced by urea nitrogen (0.06 kg/day) in ration B and C. Overall LWG has been reported with Gr. A (20.7kg) in comparison with Gr. B (13.0kg) and Gr. C (12.0kg).	302
1995	To detect the effect of feeding UMB on rice straw intake and biochemical changes in cattle	Rice straw supplemented UMB containing 3%, 6% and 12% urea for 5 days. The voluntary intake of rice straw, ruminal pH, ammonia nitrogen and BUN increased significantly in UMB supplemented cattle in comparison to control. Maximum feed intake recorded up to 9% UMB but decreased with 12% UMB	303
1995	To use cow feces <i>in vitro</i> digestibility	Cow feces has been used as a source of microorganisms for <i>in vitro</i> digestibility assay with effect of stages at different fecal concentrations & incubation periods.	304
1996	To evaluate the nutritional value of local grasses as a feed for ruminants	Certain naturally growing local grasses like durba, kanaibashi, kalimona, heicha which are available during dry and wet seasons in Bangladesh which have been used for feeding ruminants.	130
1996	To find out the percentage of smallholder farmers adopted urea-treated rice straw feeding in their cattle	About 73.1% smallholder cattle farmers have adopted urea-treated straw, 4.8% urea molasses block (UMB), 14.1% urea + molasses + untreated straw and 9.0% urea-treated straw + UMB to feed their cattle. The urea-treated straw and UMB have been shown profitable.	305
1996	Effect of feeding tea waste in a parts of the concentrate in the zebu bull calves	The sun dried tea waste collected from local restaurant has been used to feed zebu bull calves @ 100g/calf/day along with 900g concentrate showed higher LWG of 314.g / day than 239.8g LWG reported with only feeding of 1000g concentrate.	306
1996	To use cow feces in <i>in vitro</i> digestibility	Cow feces has been used as a source of microorganisms <i>in vivo</i> digestibility assays of forages.	307
1997	To determine the minimum level of leucaena required for performance of bulls	Four levels of leucaena, namely 0 (0%), 2kg (10%), 4 kg (18%) and 6 kg (27%) of dietary DM intake have been supplied to native bulls of 355 kg BW. About 20% leucaena would be required on a rice straw diet to improve animal performance.	308
1997	To detect the effect of different levels of RDP in straw based ration on purine derivatives excretion & microbial N supply in cattle	Rumen degradable protein (RDP) is required for microbial protein synthesis. Four formulated rations at the same amount of energy but varying RDP include 50 (U0), 75 (U1), 100 (U2) and 159 (U3) % level of RDP have been used for trails. Rumen NH <sub>3</sub> -N concentration increased from 43 to 130 mg/L in response of RDP intake. Purine derivatives excretion increased significantly with incremental level of 203g RDP/d (U2) intake and positively correlated with amount of RDP intake.	309
1997	To detect the effect of rice meal feed (RMF) on straw DM intake in bulls	Rice bran commonly available in Bangladesh is a mixture of hulls (60%), bran (35%) and polishing (5%), referred here as rice meal feed (RMF). RMF supplementation had no significant effect on the straw DM intake. The inclusion up to 2 kg level (25% of the DMI) has been recommended for feeding.	310
1997	To detect the effect of feeding green grass with and without rice straw <i>ad libitum</i>	Growing bulls of 304 kg BW and 32 months old fed rice straw with combination of green grass at 0, 2 kg, 4kg and 6 kg. All level of grass supplementation decreased the straw DM intake and rumen NH <sub>3</sub> -N concentration increased with the increase in grass level & ranges from 8-46 mg/liter. Green grass supplementation is often recommended for optimization of rumen environment of a straw diet but no such beneficial effect observed up to 6 kg level	311

1997	Effect of UMS on DM intake and digestibility and reduction of in vivo methane production in growing bulls	Results showed that the feeding of rice straw with 15% molasses and 3% ureas an intimate mix (UMS) in growing bulls increased its digestion and intake in association with a reduced methane emissions in the rumen. When compared with that of UMB lick, the UMS also resulted highest straw intake and digestion and LWG and accordingly UMS has been suggested for feeding in ruminants.	233
1998	To use cow feces in vitro digestibility	Cow feces has been used as a source of microorganisms <i>in vivo</i> digestibility assays of forages.	312
1998	To investigate the available feeds and feeding practices of livestock by the farmers at rural levels	Rice straw and green grass are the roughage feeds supplied by the farmers to their animals at village levels. Rice polish, wheat bran mustard oil cake are supplied as concentrate. Straw supplied as whole (dry / wet), chopped (dry / wet), and / or mixed with green grass. About 90% of the farmers are unable to offer concentrate to their animals due to high price.	313
1998	To compare the effects of wheat bran and rice polish on growth performance & nutrient utilization in growing bull calves	Three groups (A,B & C) of native growing bull calves of 20-24 months old have been supplied rice straw <i>ad libitum</i> along with 1.75 kg green grass and 250g sesame oil cake daily for 84 days. In addition, Gr. A received both wheat bran and rice polish, Gr. B wheat bran and Gr. C rice polish only. The results showed that replacement of wheat bran at 100% level in the concentrate improved feed intake, nutrient digestibility, feed efficiency and live weight gain.	314
1998	To compare the effects of different protein supplements on growth performance and nutrient utilization	Formulated three rations using rice straw, dal grass, wheat bran and supplemented with either coconut oil cake (Gr. A), sesame oil cake (Gr. B) and soybean meal (Gr. C) have been evaluated in bull calves of 105.7 kg BW for 78 days. Highest growth rate reported with coconut oil cake (TLWG 48.33kg) and utilize straw more efficiently than those of sesame (41.0 kg) and soybean (44.42kg) oil cakes.	241
1998	To detect the use of rice gruel compared to that of molasses as a source of readily fermentable energy in urea treated straw diet in growing bulls	Three groups of calves fed with urea (3%) treated straw (US), 3% US + 15% molasses (UMS) and 3% US + 30% rice gruel (UGS), respectively for 60 days. Feeding of US showed highest LWG (292 g/d) in comparison to UMS (125g/d) whereas decreased LWG (-19g/d) in UGS group. However, authors suggested to use rice gruel where molasses not available or costly.	315
1998	Effect of replacing til oil cake by poultry excreta on growth performance and nutrient utilization in calves	Results showed that the til oil cake can be replaced by dried poultry excreta in bull calves ration without any harmful effect. Approximately 50% replacement of til oil cake by ground dried poultry excreta has been recommended for growing bull calves	242
1999	Different protein supplement on growth and nutrition utilization in bull calves	Feeding of coconut oil cake, sesame oil cake and soybean meal with a basal diet of rice straw, dal grass and wheat bran have been evaluated in bull calves. Results showed that protein conversion efficiency and growth reported highest with coconut oil cake	316
2000	Evaluation of different ration in bull calves	Maize silage in combination with straw and concentrate mixture has been suggested for feeding growing animals for better performances. Fresh water hyacinth leaves has also suggested in combination with straw and concentrate	317
2000	Evaluation of pre-and post-partum supplementation of UMMB to native cows	The UMMB has been supplied to 30 cows from 6 months of pre- partum to six months post-partum period whereas 30 cows served as control fed only trade-itional feed. The supplementation of UMMB to cows resulted higher birth weight (14.61kg/12.00), calf LWG (117.0 / 55.0 g/d) but low mortality of calves (0/ 9.0%).	318
2001	To evaluate three types of rations in local bulls	12 native bull calves, 2.5 years old, live weight 139.9kg, divided into three treatment groups, studied for 66 days based on DM basis.	319

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2001	Evaluation of feeding ensiled urea-treated rice straw in cross-bed calves.	The highest LWG has been reported in calves of group C fed treated rice straw and water hyacinth in comparison to Group B fed urea-treated rice straw without water hyacinth and Group A fed only untreated rice straw.	320
2001	To compare the effects of feeding normal protein (NP), bypass protein (BP) and BP + bypass energy (BE) in two years old native bull calves	Three experimental diets consisted of basal ingredients include: rice straw, dal grass, wheat bran, molasses and urea supplemented with Til oil cake (normal protein : OC diet), fish meal (bypass protein, FM diet) and the mixture of fish meal and broken rice (bypass protein and bypass energy, FM + BR diet). Results showed that significantly higher total feed intake (kg/d) fed on FM + + BR diet (3.71) compared to those fed on FM diet (3.06) and on OC diet (3.07). So, supplementation of straw-based diets with FM + BR improved feed intake, fiber digestibility and LWG in bull calves.	321
2001	To detect the effects of UMMB supplement on LWG and ovarian activity of zebu heifers	The supplementation of urea-molasses-mineral block (UMMB) with normal diet heifers has significantly increased LWG from $49.45 \pm 10.23$ to $64.24 \pm 8.59$ kg. The ovarian activity (progesterone assay) did not show any significant LWG and ovarian activity has delayed.	322
2001	Evaluation of graded levels of cotton seed cake (CSC) on a urea-molasses-straw based diet in bulls	It has been reported that unless the proteins in being protected from rumen degradation, addition of CSC to UMS diet would have little nutritional or economic advantages. Supplementation of CSC had little beneficial effect the overall productivity of the animals based on UMS based diet in growing	323
2001	To detect the effect of feeding water hyacinth on the performance of indigenous heifers	Highest daily LWG (0.128kg/d) recorded in heifers fed rice straw (RS) + water hyacinth (WH) + green grass (GG) at the ratio 1 : 0.5 : 05 in comparison to 0.086 LWG fed with RS + GG (1:1), 0.078 fed with RS + GG (1 : 1) and 0.044 LWG fed with only fed RS. Partial replacement of GG (1:0.5:0.5) by WH has suggested.	324
2002	Effect of feeding UMS and wheat bran on LWG in steers	Feeding of mixed UMS (3.5kg/d) and wheat bran (0.5kg/d) have been reported to increase the live weight gain (LWG) @ 418.75kg / animal/day for 4 months study period in zebu steers	325
2002	To evaluate the nutritional status of locally available feedstuffs in Bangladesh	Nine roughages and nine concentrates have been evaluated with respect to the chemical composition, organic matter digestibility (OMD), ME and rumen degradable protein (RDP) content. Among the roughages, straw showed much lower of CP and RDP values with high NDF content.	326
2002	To detect the effect of urea and/or soybean treated rice straw on feed intake and growth in growing native bull calves for 56 days	Three groups of bull calves fed with 4% UTRS, 4% urea + 4% soybean treated rice straw (STRS) and 4% urea + 6% STRS. Results showed that 4% UTRS with 2 kg green grass + concentrate didn't produce any adverse effect on feed intake and growth. Soybean meal 4 or 6% added to the UTRS caused rapid hydrolysis of urea, which resulted an improvement in nutrient digestibility and better utilization of rice straw for growth of growing bull calves	327
2002	To evaluate of some aquatic plants	Mineral composition, in-vitro gas production and in situ degradation measurements have been evaluated in some aquatic plants.	328
2003	Growth performance of growing bull calves	Growth performance of crossbred growing bull calves fed by supplementing molasses with straw based diet and conventional concentrate have been reported.	329
2004	To detect the effect of phenolic compounds of legume forages on OMD and ME	The presence of phenolic compounds and their effect on organic matter digestibility (OMD) and metabolic energy (ME) content in acacia, albizia and sesbania have been reported to be contained higher CP and ME which has been suggested to use as supplement to ruminant fed low quality forages.	257

2005	Effects of protein source bacteria, NH <sub>3</sub> -N & VFA in the rumen of cattle	This research has concluded that among the protein sources, soybean meal has contributed most to the bacterial population growth, ammonia and VFA production compared to those of fish meal and leucaena leaf meal in cattle.	330
2005	Effect of different dietary energy in crossbred heifers	The effect of different dietary levels on the performance of cross-bred dairy heifers have been reported.	331
2005	Digestive performances of cattle and buffalo calves	The nutrient intake, digestibility and growth fed on maize silage and concentrated mixture have been compared between cattle and buffalo calves	332
2007	To identify types of rations have used in feeding trials in cattle	Three types of rations have been identified as (a) dry straw, (b) urea-molasses-straw and (c) grass silage based on basal roughages used in different feeding trials to evaluate live weight gain and FCR	333
2007	Influence of age on the intake, digestibility & FCR in native bull calves	Silage with supplemented concentrate feeding in three age groups of bull calves showed that the age variation above six months had no significant effect on the intake and digestibility of feed or feed conversion ratio	334
2007	Effect of feeding UMB in heifers	The effect of feeding urea molasses block (UMB) on the performance of heifer under farm condition have been reported	335
2007	Effect of Cu supplementation on nutrient utilization & Cu status in bull calves	Supplementation of copper in diet has improved only copper retention and blood copper status other than live weight gain, feed intake, nutrient digestibility, TDN and apparent and true absorption of copper	336
2007	To determine the calcium, phosphorus and ME content of four foliages	Higher Ca content has been reported in Gliricidia (0.60%) compared to Ipil-ipil-1 (0.44%), Ipil-ipil-2 (0.54%) and Calliandra (0.48%), while P (0.23-0.32%) content was not significantly different.	337
2008	To evaluate the three concentrate mixture in RC heifers	Highest LWG (25kg) has been reported with concentrate mixture consisting of wheat bran (21.7%), rice polish (22.42%), cracked maize (21.62%), mustard oil cake (13.15%), soybean meal (17.03%), DCP 2.0% & salt (2.0%) for 90 days trial.	338
2009	To investigate the bio-availability of phosphorus (P) sources in feed ingredients of cattle	From analysis of six different groups of rations it has concluded that bone meal (00.46 g/100g), mustard oil cake (00.44g/100g), sesame oil cake (0.45g/100g and poultry litter (0.45g/100g) may be used as phosphorus supplemental in cattle ration.	339
2010	UMB on growth performance of RCC×HF bulls	The effect of urea molasses block (UMB) on the growth performance of Red Chittagong and Holstein-Friesian crossbred bull calves have been reported.	340
2010	Performance of buffalo & cow calves supplemented with UMB with straw based diet	The cow calves (1 year & 8 month age and 111kg BW) and buffalo calves (1 year & 10 months age and 89 kg BW) have been fed UMB 0.5 kg/d/animal for 60 days with straw based ration. The BWG has been reported to be higher in buffalo (0.40 kg/day) than cow calves (0.36 kg/day) by feeding UMB with straw based diet.	341
2010	To investigate the use of Triple super phosphate (TSP) as a source of Phosphorus in growing bulls	Four groups of local growing bulls of 30 months old with 150 kg BW are used for this trial for 60 days. TSP has supplied as 0 (T-0), 0.5 (T-1), 1.0 (T-2) and 1.50 (T-3) kg/100 kg diet. The mean serum P levels fed diet T-1, T-2 and T-3 has been reported P levels fed diet T-1, T-2 and T-3 has reported significantly higher than that of animals fed on diet T-0. Therefore, supplementation of 0.21% P from TSP may be used in growing bulls.	342

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2010	To detect the nutrient digestibility and growth of native bull calves by feeding urea and urease enzyme sources treated rice straw for 75 days	Digestible nitrogen free extract (DNFE), digestible organic matter (DOM), total digestible nutrient (TDN) contents and LWG have been reported to be significantly higher in diet of 3.5% UTRS + 2.5% chick pea or 2.5% midden soil treated ensiled straw. Suggested to feed such diet consisted of UTRS + 3.5% chick pea to growing bull calves after 7 days of ensiling.	343
2010	Effect of protein density of conc mixture on growth performance of RC heifers	The CP concentration of 20% in conc mixture containing 10.5 MJ reported cost effective with the UMS-based diet of RCC heifers for better nutrient digestibility and growth	344
2012	To detect the effect of fish meal on growth & reproductive performance in crossbred heifers	Supplementation of fish meal (5-10% of concentrate) with rice straw based diet have been reported as a best option to obtain better performance in terms of DMI, digestibility, daily weight gain and reproductive performance especially estrus in crossbred heifers.	345
2013	To detect the feed efficiency of breeding bulls	Residual feed intake has reported to serve as an appropriate selection tool for improving feed efficiency of breeding bulls without adversely affecting early growth performance of the progeny.	346
2013	To evaluate the quality of rice straw through treatment with urea and midden soil for large ruminants	Midden soil has been reported to be a good source of urease enzyme which is found in lower part of the cow dung pit. The DOM, CP, DCP, DNFE and TDN contents have been reported significantly higher in straw based diet treated with 3.0% urea and 5.0% midden soil. Suggested to use rice straw treated with 3.0% urea and 5.0% midden soil for feeding	347
2013	To use of wastage with poultry droppings and oat forage as a cattle feed	Results showed that ensiling oat forages up to 60% caged layer excreta and 5% molasses significantly improved the nutritional values of wastage with oat forages.	348
2013	Effect of particle size of para grass and maize grain on crossbred heifers	The effect of particle size of para grass and maize grain on intake, digestibility and growth performance of crossbred heifers have been reported	349
2014	To compare the effect of feeding between molasses and rice gruel on growth performances of growing calves	Two groups of calves of 20 months of age with mean BW 193.3kg have been used for feeding of 2% molasses of concentrate mixture and rice gruel @ 2 liter/ 100 kg BW once in a day for 60 days. No significant differences has been reported between two groups in the gain of body weight.	350
2015	To detect the effect of single and twice times drenching of soybean oil for growth performance in growing bulls	Each of the bull calf has been drenched with Soybean oil @ 3g/kg BW single and 2 <sup>nd</sup> dose after 30 days after the first dose. All the cattle fed <i>ad libitum</i> straw based diet supplemented with urea-molasses (3% urea, 20% molasses) plus a concentrate mixture. A single dose drenching of vegetable oil at farmer level resulted better growth performance in cattle.	351
2015	To detect the effect of UMS and UMS + Conc. feeding in Brahman (L × B) cross bulls	Feeding a mixed concentrate as a supplement to a UMS diet increased the growth performance of crossbred (L × B) bulls. Replacing 50% of an all concentrate diet with urea-molasses impregnated straw reduced growth rate only slightly, led to proper feed conversion.	352
2015	To detect the effect of feeding matikali on feed intake, digestibility and growth rate in local bull calves	Indigenous bull calves, aged between 2 to 3 years with average live weight 83.4 kg have been used for feeding diets with matikali ( <i>Vigna mungo</i> ) to detect the feed intake, digestibility and growth rate. Supplementation of straw-based diets with vigna hay improves linear improvement of feed intake, nutrient digestibility and LWG in calves	353

2015	To detect the effects of genetic and non-genetic factors on growth traits of crossbred calves	Both the genetic and non-genetic factors like season, sex, year of birth, had no significant effects on growth traits in crossbred dairy cows. But year of birth and dams' milk yield capacity have been reported to be played significant role for the considered growth traits of calves.	354
2016	To detect anthelmintic efficacy of neem & ata leaf & effect on milk yield & LWG in cows	The anthelmintic efficacy against gastro-intestinal parasites in lactating cows in order of albendazole > neem leaf > ata leaf. Increased milk yield has been reported significantly (p < 0.01) after 28 days of treatment. No significant differences on LWG in the three treatment groups	355
2017	To find out the suitable ration/diet for the rapid growth and fattening of the cross-bred bull calves	Highest LWG (25.33kg) in crossbred bull calves has been reported with a ration (g/100g DM) composed of rice straw (16.45), green grass (29.62), crust maize (29.62), wheat bran (3.62), rice polish (3.62), mustard oil cake (13.15) and common salt (3.92).	356
2019	Effect of protein rich ingredients into conc. diet on BWG in heifers	Feeding of soybean meal and mustard oil cake added in concentrate with para and German grasses as basal roughage resulted 16% higher LWG than control heifers. Protein supplement also increased the growth measurements and blood serum status.	357
2020	To evaluate the effect of conc supplement on growth, milk yield and reproductive response in crossbred cows	Results showed that supplying an additional amount of concentrate to the cows before and after two months of freshening had a positive influence on milk production as well as reproductive performance. Basal diet – 22 kg green fodder (Para : German = 2 : 1) and 2.0 kg conc (wheat bran 82.28, mustard oil cake 13.72, salt 3.7 and DCP 0.3%)	358

Table 7. Effects of different feed formulations on productive and reproductive performance of **dairy** cattle

Year	Research objectives	Major findings	References
1969	To evaluate the economical limited roughage feeding	Limited roughage feeding would be economical provided a certain minimum level (1% hay equivalent) of roughage in the ration of <b>lactating cows</b> is maintained.	359
1974	Effect of voluntary roughage intake and its economic influence on milk yield in cattle and buffaloes	The DM intake and feed efficiency of Murrah buffalo have been reported to be higher than cattle both the Sahiwal and Red Sindhi breeds. The feed cost in buffaloes in terms of milk production has not that much high which could possibly compensate higher feed cost.	360
1980	To compare the effect on milk production in lactating cows fed 3 different grasses	German, napier and para grasses have been fed ad libitum to lactating cows to detect their effects on milk production. Feeding of German grass caused better result in respect of quality and quantity of milk in comparison to Napier and Para grasses	361
1982	Effect of feeding UTS on Milk yield composition in lactating cows	The milk yield and milk fat (%) increased due to feeding UTS in lactating cows but it has no effect on solids-not-fat (%) and total solids (%). Feeding of UTS has increased digestibility, utilization of straw and as a source of NPN.	362
1984	Effect of feeding urea-treated rice straw (5%) on milk constituents of Pabna variety cows	Two groups (A & B) of cows, of which cows of group A fed urea-treated rice straw and group B fed untreated rice straw. Higher fat (%) has been reported in urea-treated cows (5.7%) in comparison to cows fed untreated straw (4.76%). The SNF and total solids did not differ significantly.	363
1987	To detect the effect of fish meal supplement on milk of lactating cows	Fish meal has been supplied in three different groups of cows resulted higher final LW (kg) and milk butter fat (g/kg) in cows fed 600g (198kg; 50g), followed by 500g (161kg; 49g) and 400g (178kg; 41g) fish meal, respectively.	364

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1988	Effect of feeding water-hyacinth on milk yield in lactating dairy cows	Feeding of rice straw (RS) & German grass (GG) (1:1), RS + GG + water-hyacinth (WH) (1 : 0.5 : 0.5) and RS+ WH (1 : 1) in lactating cows insignificantly increased up to 192.9,182.5 and 197.5 ml/liter, respectively.	365
1990	To detect the effect of different levels of fish meal in cross-bred dairy cows in late lactation	Fish meal levels 0, 400 and 800 g /day/cow have been supplemented in crossbred dairy cows in the 8.5 months of lactation and continued for 2 months with straw based diet resulted in increased milk yield and milk protein with up to 400g / head /day fish meal supplied group of cows.	366
1990	To detect the effect of different levels of fish meal in Pabna variety at early lactating cows	Fish meal levels 100, 200 and 300 g/cow/day have been supplemented at 3 weeks of lactation stage on the basal diet includes 5% UTS, green grass and wheat bran. The results suggested that 200-300g/day fish meal in UTS based diet may be prescribed for beneficial effects.	367
1990	Effect of ammoniated straw on milk yield in native lactating cows	Comparatively higher average milk production per day has been reported with ammoniated straw supplemented cows 0.52 and 0.57L/cow/d) in comparison to non-supplemented cows (0.45 and 0.46 L/cow/day)	368
1990	Effects of feeding urea-treated rice straw on milk composition of cows	Milk composition especially protein, fat, ash, total solids and solids-not fat content have been reported to be increased significantly in cows fed with urea-treated rice straw than untreated rice straw that increased the quality of milk.	369
1990	Effect of feeding urea-treated rice straw in native cows	The effect of feeding urea treated and untreated rice straw with undegradable protein on voluntary feed intake, milk yield and body weight changes of local cows have been reported	370
1991	To investigate the milk production, disposal pattern and marketing	An average of 34.2% families have lactating cows and an average of 1.68 liter milk is produced / cow. Out of total milk production, 58% of milk is consumed, 41% sold and 1.0% distributed.	371
1992	To compare the effect of fish meal and wheat bran on lactating cows	Insignificantly higher av milk yield (0.75 and 0.71 L/d), butter fat (79 & 75g/kg), milk protein (52 and 47 g/kg) and LWG (0.16 and 0.12kg/d) have been reported in cows fed with fish meal in comparison to cows fed wheat bran, respectively. So, wheat barn can replace the costly fish meal in lactating dairy cows.	372
1992	Effects of feeding ammoniated rice straw supplemented with UMB licks	Comparatively higher DM intake and milk production in lactating cows fed with ammoniated rice straw supplemented with urea molasses block (UMB) lick than untreated and supplemented control lactating cows	373
1993	To detect the effect on LWG and milk yield in lactating cows fed urea-treated rice straw	Results showed that the average milk yield reduced (2.96 to 2.68, 4.13 to 3.62 & 3.46 to 3.23 kg/d) but LWG increased for dairy cows by feeding urea treated rice straw. The cost and return analysis showed negative result and found uneconomic for lactating cows	374
1993	To determine the urea level in milk in lactating cows fed urea treated & untreated rice straw	The urea level in the milk of lactating cows fed with urea treated rice straw increased (27.07-59.97 with an average $35.29 \pm 1.87$ mg/100ml) significantly ( $p < 0.05$ ) in comparison to lactating cows fed untreated rice straw (1.39-39.57 with an average $24.16 \pm 5.13$ mg/100ml)	375
1994	Effect of feeding UTRS in composition of milk in lactating cows	Results showed that feeding of UTRS in lactating cows increased the gross energy value (3.28 vs 3.05 MJ/kg), milk fat (43.40 vs 38.80g/kg) and solids-not-fat (90.0 vs 87.20 g/kg) in comparison to feeding of untreated rice straw, respectively.	376
1994	Effect of supplementing urea molasses block lick (UMBL) on performance of cows	The feeding UMBL with straw based diet improved the daily milk yield, extended lactation period, shorten dry period and higher calving rate compared to non-fed UMBL cows. The higher birth weight of calves of dam fed with UMBL (16kg) in comparison to 14kg in dam without UMBL.	377

1994	To detect the effects of genetic and non-genetic factors on milk yield & birth weight of calves	Highest milk yield has been reported in the pure Friesian cows followed by and Sahiwal at CCBSDF. The average daily milk yield has been Jersey reported lowest in first lactation and gradually increased up to 8 <sup>th</sup> lactation. Male calves had higher birth weight than female calves	378
1995	Effect of feeding UMS on milk production and its economics on Pabna variety lactating cows	The effects of feeding UMS on milk production has been studied on Pabna variety lactating cows for 60 days. Cows fed UMS as a replacer of dry straw increased daily milk yield by 1.37 liter which has reduced the daily requirement of 1.0 kg /cow concentrate.	379
1995	To compare the effect on milk yield between cows feeding with rice straw plus legume and only legume as a control in the bathan	In addition to the basal diet, both the groups have also supplied with 4.0 kg/cow/day concentrate. Both the initial and final LWG and daily yield (liter/day/cow) have been reported to be increased significantly in 'rice straw & legume' fed group (338.06/344.33kg and 8.24/8.64L) than only legume fed group (329.87/330.25kg and 7.68/7.74L) respectively of lactating cows. Feeding of straw @ 2.5 kg/day/cow has reduced legume consumption @ 12kg/d/cow.	380
1996	Effect of feeding of urea-treated rice straw + fish meal on induction of estrus in crossbred heifers	The crossbred (Sahiwal × Pabna variety) heifers aged 4 years which have been fed 5% urea-treated rice straw supplemented with 150g of fish meal daily had shown estrus but those heifers fed ≤ 100g fish meal did not show any signs of estrus during the 14 weeks of experiment.	381
1996	To detect the effects of parity and lactation stages on milk yield in Sindhi cross cows	This study has reported significantly highest milk production in Sindhi crossbred cows at early lactation up to 90 days in all the three parities (416.40, 375.0 & 299.20L) in comparison with mid of 90-180 days (276.85, 249.4 & 263.15L) and late of 181-270 days (183.85, 156.6 & 174.7 L) lactation stages.	382
1996	To compare the DMI & milk yield between cross-bred & native cows	The dry matter intake and milk yield of local and crossbred cows have been reported to be 4.10% and 3.10% live weight and 2.5 liters and 9.7 liters per cow per day, respectively.	383
1999	To evaluate the effect of UMMB on reproductive performance of post-partum zebu cows	Feeding of urea molasses multi-nutrient blocks (UMMB) with 10% urea @ 250g/day/cow along with the traditional feed from calving to 6 month of post-partum period resulted better reproductive performance of zebu cows under village conditions.	384
1999	To evaluate the effect of replacing conc. by urea-molasses in the diet of cross-bed dairy lactating cows	Highest milk yield (4.4 L/cow/d) has been reported with 7.0% replacement of concentrate with urea-molasses in comparison with 9.6% (3.0 L/c/d), without replacement (2.8 L/c/d) and 19% (2.1L/c/d) replacement during the 91 days study period. Overall milk composition has reported better in only concentration feeding cows.	385
2000	To explore the extent of urea level in milk and blood of cows fed with three different types of urea molasses blocks	Three types of blocks such as medicated urea-molasses-mineral block (MUMMB, 7% urea), urea-molasses-mineral block (UMMB-1, 7% urea) and UMMB-2 (21% urea) have been used @ 250g / cow/day to detect urea level in milk and blood of native lactating cows. Both the feeding of UMMB -1 and UMMB-2 increased the urea levels in both in the milk and blood significantly in comparison to the initial levels.	386
2000	Effects of urea molasses multi-nutrient blocks (UMMB) on BW and milk yield in native cows	The UMMB with 6, 8 and 10% of urea have been used @ 250g/d/ cow resulted higher LWG, milk yield and BCS with supplemented UMMB contained 10% urea than other groups. The UMMB with 10% urea may be recommended up to 6 months of post-partum for more milk yield and better health of native cows.	387
2001	To detect the effects of feeding UMB on milk yield and LWG in lactating crossbred cows	Four levels of UMB: 0 (T), 350 (T1), 500 (T2) and 650 (T3) g/ d/cow have been supplied to lactating cows resulted similar but higher av. lactation milk yield (6.03 & 6.05L) in groups T2 & T3 in comparison to T (4.80L) and T1 (4.86L) groups.	388

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2001	To detect the beneficial effect on milk yield by feeding supplementary concentrates containing more UDP	Three groups of native lactating cows, of which two groups have supplied un-degradable protein (UDP) concentrate by keeping one group as untreated control. Feeding of supplementary concentrate containing more UDP showed higher milk yield (1.79 & 1.69 L/d/c) than untreated (1.32L/d/c) native lactating cows.	389
2001	Effects between mustard and sesame oil cake on milk yield and LWG in lactating dairy cows	The sesame oil cake supplement resulted higher LWG (0.77; 0.35 kg/d) and milk yield (4.39 ; 4.17 L/d) than supplement of mustard oil cake (MOC) in dairy cow ration, respectively. However, MOC (9.97%) could replace costly sesame oil cake and reduce the milk production cost in the dairy cows.	390
2002	To detect the effect of legume forage supplementation on milk yield in Pabna variety cows	The milk production has been reported to be increased in Pabna variety lactating cows supplemented with legume forage to rice straw-based diet from 2.70 liter to 3.30 liter/day /cow. Only 20% level of forage to rice based diet has been recommended	391
2002	Effect of feeding of UMS on productive and reproductive performance of native cows	The comparatively higher average milk yield (2.52 / 1.83 L/d) and calf LWG (139.35/ 96.99 g/d) and lower values of average calving to 1 <sup>st</sup> service interval (113.0/182.0 days), average calving to conception interval (134.0/210.0 days) and No. of service/conception (1.94 / 2.11) have been reported, respectively.	392
2002	To detect the effects of restricted and <i>ad libitum</i> feeding during last trimester of pregnancy on the performance of cows	<i>Ad libitum</i> feeding of cows at pregnancy caused to deposit more fat and gain weight at pre-calving resulted less milk yield during post-calving. Feeding <i>ad libitum</i> during last trimester of pregnancy is neither economic for getting maximum milk yield nor for calf growth rate and MAFF recommended level of dietary energy during third trimester of pregnancy could be applied in cows.	393
2003	To detect the effects of supplementing UMB & UMMB on LWG, BCS, milk yield & composition in dairy native cows.	The initial and final LW (kg) of Gr. A (Control: 239.3; 238.3), Gr. B (UMB: 205; 206.8) and Gr. C (MUMB: 240; 242.6), and initial and final milk yield in liter between 31-45 days of Gr. A (2.5 ; 2.0), Gr. B (2.5 ; 3.03) and Gr. C (2.5 ; 3.42) have been reported. Both LWG and milk yield have increased in both the supplemented groups in comparison to control group.	394
2003	To compare the effect of concentrate supplement with control on milk yield in RCC	Out of the three groups, Gr. A has supplied wheat bran 375g, sesame oil cake 125g, fish meal 75g and molasses 20g, and Gr. B has received wheat bran 375, sesame oil cake 125g, molasses 104g and urea 11g and Gr. C served as untreated control. The higher TLWG (kg/cow) and milk yield (L/C/d) have been reported in Gr. A (6.0 & 2.2) than Gr. B (4.0 & 2.0) and Gr. C (1.5 & 1.8), respectively.	395
2004	Effect of UMB supplementation on post-partum reproductive performance in crossbred dairy cows	Two groups of crossbred cows, of which one group received control diet and another group received UMB supplemented diet. The UMB supplemented with basal diet has improved the reproductive efficiency and the better performance reported in Sahiwal cross than Holstein cross cows.	396
2004	Effect of feeding UMMB on health and productive performance in zebu lactating cows	The urea molasses multi-nutrient blocks (UMMB) has been fed @ 250g/cow/day to zebu post-partum cows from the date of calving to the date of confirmation of pregnancy. Positive effect of feeding UMMB has been reported on LWG, milk yield, BCS in cows and LWG in calves under rural condition	397
2004	To detect the effect of feeding UMMB on reproductive performance of post-partum native cows	UMMB @ 250g/cow/day has been fed from the calving that decreased the days of calving to 1 <sup>st</sup> service (130 & 194), calving to conception (162 & 199) and calving interval (443 & 480) in comparison to their respective control cows. UMMB supplement with straw based diet has appositve effect on reproduction.	398

2004	Effect of feeding UMMB on health and productive performance of zebu lactating cows	Out of the two groups of cows, Gr. A has fed with rice straw based basal ration whereas the Gr. B cows received UMMB @ 250g/d/c in addition to basal ration. The higher LWG in cows and calves, BCS, milk yield (1.93 / 4.43L) and DMI in comparison to control Gr. A	399
2004	Effects of pre-and post-partum energy level and feeding pattern on the performance of crossbred cows and their calves under farm conditions	Two groups of selected dairy cows, of which one group fed 30% less and another group 30% more energy than MAFF's (1984). At post-calving all cows fed same diet <i>ad libitum</i> to assess the effects of feeding during pregnancy on their performance. This study reported that 30% less dietary energy level of MAFF's (1984) recommendation during the last trimester of pregnancy not suitable for crossbred cows.	400
2005	Effect of supplement of UMB lick in dairy cows	The effect of feeding supplementing UMB with straw-based diet on productive and reproductive performance of cross-bred dairy cows have been reported.	401
2005	To detect the effect of UMB feeding on productive and reproductive performances in crossbred (HF × L) lactating cows	Higher milk yield (6.29 / 4.75L/d & 5.57 / 4.48L/d) and LWG LWG (135/18g /d & 50/22g/d) have been reported on feeding of UMB in cows in both the dry and rainy seasons, respectively. Calving to 1 <sup>st</sup> estrus, conception and calving interval has been reduced and obtained better economic return with UMB supplement in cross-bred cows.	402
2006	To detect the effect of feeding ration with poultry droppings on yield and composition of milk in cows	Wheat bran (53%) (Gr. A) has been replaced by 10% (Gr. B) and 20% (Gr. C) dried poultry droppings in ration of lactating crossbred cows. Average daily initial and post-treated milk yield in Gr. A (4.2 ; 4.482 L), Gr. B (4.2 ; 3.8) and Gr. C (4.2 ; 4.6). Suggested that 20% wheat bran can be replaced by droppings.	403
2006	To determine the effect of UMMB supplementation on productive and reproductive performances in cross-bred cows	Two nutritional groups (A & B) of crossbred cows, of which both the groups received rice straw (3kg), concentrate (2kg) and green grass (15-16kg) but Gr. B supplied with UMMB @ 250g/ per day per cow. Higher average LWG has been reported in Gr. B (18.3 ±3.2kg) than Gr. A (8.4 ± 3.4kg). Similarly, higher av milk yield (L/d) and lactation yield (L) have also be reported in Gr. B (4.8 & 432.0) than Gr. A (3.3 & 297) cows.	404
2006	To detect the impact of dairy farming and labor	There is a significant inefficiency effect in the dairy farming and labor has negative impact on the inefficiency effect for all types of farms	405
2007	Influence of drenching oil for milk production	Drenching of oil for increased protein availability for determining milk production of dairy cows have been reported.	406
2009	To detect the effect of feeding on productive and reproductive performance in deshi cows	Dhaincha (0.7kg/day) and Ipil-ipil (0.8kg/day) could be used as alternative sources of protein for ruminants, which may result in better weight gain, milk yield and reproductive performance during post-partum period in indigenous cows.	407
2009	To detect the effects of maize-based concentrates on milk yield in cows	Two groups (A & B) of cows fed basal roughages (straw & green grass) with concentrate @ 1kg/ 100kg BW daily for 60 days. The maize-based concentrates feeding in cows led to better milk yield with good economic return.	408
2009	To detect the effects of UMRS productive and reproductive traits of RCC	Two groups (A & B) of RCC, of which Gr. A fed UMRS, green grass & conc., whereas Gr. B fed rice straw, green grass & conc. feeding UMRS adversely affected the reproductive performance. But no changes in milk yield (2.0 / 2.0 kg/d). Feeding of UMRS has been reported not suitable for breeding bull because it decreased volume (3.0/3.7 ml) and motility (58.6 / 68.4%) of sperm.	409

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2010	To detect the effect of different rations on productive and reproductive performance in dairy cows	Three groups of lactating cows have been used for trial of three different conc. to detect milk yield, services per conception, calving to 1 <sup>st</sup> service interval and pregnancy rates in native and crossbred cows. Feeding intervention had significant influence on services per pregnancy, calving to first service interval and milk yield.	410
2010	Urea-molasses treated straw technology	Field trial and demonstration of urea molasses straw technology of feeding lactating animals have been reported.	411
2010	To detect the effect of vitamin-mineral supplement on productive and reproductive performance of lactating cows	Two groups (A & B) of cows, of which control group has provided conventional diet and supplemented group has provided Vitamix powder @ 1g/ 1kg concentrate powder @ 1g/ 1kg concentrate for two months before calving. The micro-nutrients supplementation has improved the BW of pregnant cows (137.16/186.33kg), birth weight of calves (17.33 / 19.33kg), milk yield (3.07/4.10kg/d), and fat (36.9/ 39.7g/kg) content of milk.	412
2010	To detect the effect of feeding Napier grass on Ca and P level in cattle	Relationship between increase of oxalate intake from Napier silage and these ingested oxalate combine with available calcium in the rumen that formed insoluble calcium oxalate and excreted in feces at a higher level than that of phosphorus.	413
2012	Effect of genotype & lactation on milk composition	The effect of genotype and lactation on milk urea nitrogen, blood urea nitrogen and milk composition of dairy cows have been reported.	414
2012	Effect of dietary protein on BUN in native cows	The feeding effect of dietary protein sources on blood or milk urea nitrogen in native cows.	415
2014	To evaluate the feeding effect of di-calcium phosphate (DCP) on Ca balance & BCS of dairy cows fed Napier grass	The oxalate content of the Napier grass has been reported as 3.77% of the DM in early summer season. Soluble oxalate can bind with Ca in the intestines and in the blood to form insoluble CaO crystals, lowering blood Ca levels. Diets with 150 g DCP has been suggested for optimizing Ca balance and BCS of dairy cows fed Napier grasses.	416
2015	Effect of different rations on milk yield in cross-bred lactating cows	Feeding of legume hay (khesari hay + concentrate) has produced highest milk yield (10.76L/d), followed by UMS + concentrate (10.76 L/d), Napier silage + + concentrate (9.86 L/d) and lowest with rice straw + concentrate (7.31 L/ d).	617
2015	To estimate the milk urea nitrogen (MUN) and its risk factors in crossbred cows	The milk composition along with MUN (6.7-29.0 with average 14.58 ± 0.158) of crossbred lactating cows (n=724) and associated risk factors (season, parity & herd size) have been evaluated. Results showed that herd category and parity influenced the MUN levels.	418
2017	To detect the effect of Ca-salt of fatty acid on milk yield	German grass + concentrate mixture + 2.5% soybean based calcium salt of fatty acid has reported to be produced highest milk production et in comparison to other groups.	419
2017	To compare effects of restricted and standard feeding on reproductive performance in heifers	The average level of estrogen and progesterone have been decreased significantly in restricted feeding than standard feeding heifers. Under-feeding heifers have showed irregular estrus and anestrus. Standard feeding has been suggested to improve the cattle production efficiency	420
2017	To investigate the feed and nutrient intake and status and performance of the RCC	The total LWG of pre-natal RC cows has recorded to be 14.50kg and the calf's birth weight 10.95kg. The pre-natal nutrition of cows affected the LWG of cows the LWG of cows before calving and calf birth weight. Improved small scale farm feeding has been suggested to obtain optimum production.	421

2018	To evaluate the concentrate supplement on the performance of lactating RC cows	The farmers' diet (63%) plus formulated concentrate to meet 100% requirements of lactating RC cows significantly increased the milk production (4.82 vs 2.4kg/d), milk fat (5.45 vs. 4.32%) and decreased the post-partum anestrus period (62 vs. 104 days) and service/ conception.	422
2018	To monitor the influence of green grass-based diet on growth & reproductive performance in dairy heifers	Heifers fed with green grass, soybean hay and concentrate had significantly higher heart girth gain, serum Ab, urea and BUN than the heifers of other groups. Supply of green grass especially a mix of leguminous and non-leguminous have been reported to be advantageous in heifer feeding.	423
2018	To investigate the effect of different types of silage on milk production in dairy cows	Maize or chopped Napier silage have been reported to be an effective alternative to green fodder during fodder scarcity for continuing milk production in dairy cows. Maize silage found better than Napier silage and chopping napier silage reported better than whole Napier silage.	424
2018	Effect of pre- and post-Partum conc supplement-Action in crossbred cows	Results showed that offering superfluous concentrates (25% of total conc) during pre-and post-partum resulted positive impact on milk yield, milk protein and post-partum heat period.	425
2019	Effect of mixed or block Form ration in milk yield Native cows	Total mixed ration (TMR) either in block (3.61 L/d) or mash (3.61 L/d) forms resulted significantly higher milk yield in native cows for the period of 45 days. TMR & block ration consisted of Maize stover 50% & roughage 50% & conc. included wheat bran (8%), kheshari bran (4%), soybean meal (25%), molasses (10%) and salt (0.5%).	426

Review of research of reports on the nutritional trials on native male cattle reveals that three major types of feed formulations have been tried based on basal roughages to evaluate the growth performances since 1965 in Bangladesh.<sup>333</sup> These three categories of the evaluated rations include (a) dry straw, (b) urea-molasses-straw and (3) Fodder & silage based diets (Table 8). In Bangladesh, 27 to 49% of cattle feed is based on rice straw, only Sirajgonj and Chittagong districts have limited, periodic grazing facilities, fodder (Napier) cultivation has been reported are in practice in Sirajgonj and Satkhira and fodder availability increased milk production and decreased disease occurrence.<sup>243</sup>

### Ration increased milk production

- In addition to rice straw, feeding of 22 kg green fodder (Para : German = 2 : 1) and 2 kg concentrate (wheat bran 82.38%, mustard oil cake 13.32%, common salt 3.7% and DCP 0.3%) in lactating cows increased milk production and reproductive performance.<sup>358</sup>
- German, Napier and Para grasses have been fed *ad libitum* to lactating cows but German grass caused higher milk production in comparison two other grasses.<sup>361</sup>
- German grass + concentrate mixture + 2.5% soybean based calcium salt of fatty acid has reported to be produced highest milk production in comparison to other groups.<sup>419</sup>
- The milk production has been reported to be increased in Pabna variety lactating cows supplemented with 20% legume forage to rice straw-based diet.<sup>391</sup>
- Dhaincha (0.7kg/day) and Ipil-ipil (0.8kg/day) have been suggested to be used as alternative sources of protein for ruminants, which resulted in better weight gain, milk yield and reproductive performance during post-partum period in indigenous cows.<sup>407</sup>
- The oxalate content of the Napier grass and its silage has been reported to be high in comparison to other fodders as 3.77% of the DM. Soluble oxalate can bind with calcium in the

rumen and intestines that formed insoluble calcium oxalate and excreted in feces at a higher level and even in the blood to form insoluble CaO crystals, lowering blood Ca levels.<sup>413,416</sup>

Table 8. Effect of feeding different diets on growth of native male cattle

S/ N	Feed type & comparison	Conc. %	No. of animals /diet	Days on feed	Daily intake of total nutrients / head			Initial live wt. kg	Daily gain g/head	FCR	Ref. No.
					DM, kg	ME	CP, g				
I. Feeding effects of straw and supplement											
A.	Straw + grass + concentrate	9.0	4	56	4.1	-	480	127	420	10.2	402
		9.0	4	56	4.09	-	486	127	442	09.39	
		9.0	4	56	4.18	-	496	126	457	09.43	
B.	Straw + Conc.	39.7	4	60	4.65	-	-	123	473	-	403
C.	Straw	0	4	60	3.84	20.1	110	276	-19	-	294
D.	Straw + Conc.	0	4	28	4.74	21.95	246	264.5	-186	-	404
		29.6	4	28	6.08	31.47	568	267.8	346	-	
		42.2	4	28	6.41	36.9	1070.8	264.8	554	-	
E.	Straw + Conc.	46.6	4	43	6.43	-	563	281	669	9.63	220
F.	Straw + Conc.	0	4	120	4.26	-	-	145	204	-	304
II. Feeding effects of urea-molasses-straw (UMS)											
A.	UMS	0	4	93	4.66	41.2	341	263	233	26.0	217
B.	UMS	-	5	60	-	-	-	319	982	-	403
C.	UMS	0	4	60	4.81	27.64	113	272	292	-	294

### Evaluation of feeding of urea-molasses treated straw in cattle

Rice straw is the major sources of roughages for cattle which are characterized by low level of CP and high level of structural polysaccharides that affect the DM intake, digestion and ultimate performance. This low quality roughage can be improved by physical, chemical and biological methods and treatment with nitrogen sources of ammonia and energy. In Bangladesh, research reports on different methods of feeding urea in cattle have been published. Some of these are: Urea-treated rice straw (UTRS),<sup>294,296,298,305,315,327,343,362,369,370,376,379,381</sup> Urea water soaked straw (UWSR),<sup>294</sup> urea-ensiled straw (UES),<sup>294</sup> urea-molasses straw (UMS),<sup>325,352,385,392</sup> urea molasses block (UMB)<sup>297,303,335,340,341,373,377,388,394,401,402</sup> urea-molasses solution (UMS),<sup>298</sup> and urea-molasses-mineral block (UMMB).<sup>318,322,384,386,387,394,392,398,399,404</sup> The UMS which is usually enriched with 3.0% urea and 15.0% molasses on dry matter basis whereas UMMB usually consisted of urea 10%, molasses 39%, rice polish 20%, wheat bran 20%, calcium oxide 6% and common salt 5%.

- The LWG has been reported with feeding UTRS in growing bull calves<sup>340</sup> but it has been reported that feeding of UTRS found not suitable to breeding bulls because it decreased quantity (3.0 / 3.7 ml) and quality i.e. motility of spermatozoa (58.6% / 68.4%).<sup>385</sup>
- The supplementation of UMMB @ 250g/cow/day with normal ration in local post-partum cows reported increased LWG and milk yield<sup>397</sup> and decreased calving to 1<sup>st</sup> service, calving to conception and calving interval.<sup>398</sup> whereas the supplementation of UMMB with normal ration in heifers has significantly increased LWG from 49.45 to 64.24 kg but the ovarian activity has delayed.<sup>322</sup>

- The urea level in the milk of lactating cows fed with UTRS (35.29 mg/dl) and UMMB @ 250 mg/cow/day increased significantly in comparison to untreated control cows (24.16 mg/dl).<sup>375,386</sup> In addition, better milk composition in only concentrate fed cows in comparison to UMMB supplement has been reported.<sup>385</sup>
- The UMMB supplement @ 250g/head/day reported a positive effect on the productive and reproductive performance of cross-bred lactating cows<sup>404</sup> but urea feeding in dairy cows reported that it may adversely affect early embryonic development.<sup>427</sup>
- Review of these reports reveal that the breeding bulls and dairy cows including lactating cows are not suitable for feeding any forms of urea-molasses straw preparations.

It appears that the lack of pasture land with shortage of cattle feeds is one of the main constraints for development and production of cattle in Bangladesh. The cattle feeds and feeding practices have been suggested to be enhanced by biotechnology to develop better cattle nutrition packages. The ultimate goal of using nutritional biotechnology in animal feeds and feeding systems is then to improve the plane of nutrition through the feeding of urea-molasses treated rice straw other than breeding and dairy animals, roughage improvement using non-toxic fungus especially white rot fungi due to its ability to dignify the plant materials, produce genetically modified fodder crops, use of genetically modified micro-organisms to enhance rumen fermentation and thereby increase nutrient availability to the host cattle and use of enzymes to improve the availability from feed and to reduce the wastage of the feed. However, the application of nutritional biotechnology in cattle feeds and feeding practices has limited value due to current status of technology, prevailing environmental and social constraints in Bangladesh.

### **Effects of heat and transport stress in dairy cattle**

Stress may be considered as anything that is applied to an animal from an outside source that has an effect on that animal's normal physiological activity. Stress can be categorized into four major types as: ① Environmental stress- toxic metal pollutants, chemical fertilizers and pesticide contamination, ② Physiological stress- heat stress, advanced pregnancy, dehydration and cold stress, ③ Nutritional stress- acidosis, bloat, hypocalcaemia, ketosis, hypomagnesaemia, and mycotoxin / plant toxins and ④ Managemental stress- handling and transportation and seasonal changes. Among these stressors, heat stress causes more losses to dairy cattle.<sup>428</sup> High environmental temperature and high relative humidity is the primary factors that cause heat stress in dairy animals.

### **Temperature humidity index (THI)**

The combined effect of temperature and humidity can be measured by the use of THI, which is calculated by the formula:  $THI = 0.72 (W + D) + 40.6$  where, W = Wet bulb temperature °C and D = Dry bulb temperature °C

The THI values of  $\leq 70$  are considered comfortable, 75 to 78 stressful and a value  $> 78$  causes extreme distress with lactating cows being unable to maintain thermo-regulatory mechanisms or normal body temperatures. It appears that the stress caused by heat and transportation in cattle have been reported from Bangladesh (Table 9).

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Table 9. Effects of heat stress on health and production in dairy cattle			
Year	Research objectives	Major findings	References
1967	Effect of climate on dairy cattle production	Climatological factors influencing dairy cattle performance have been reported	429
2016	To detect the effect of heat stress on milk yield and composition in HF crossbred cows	The HF crossbred lactating cows fed with green grasses(German, Para) <i>ad libitum</i> and concentrate @ 2.0 kg/day/cow. The effect of heat stress on milk yield and composition have been analyzed based on barn temperature and RH%. Heat stress has found strong effect on milk yield and composition of HF crossbred cows in Bangladesh. Management strategies could be helpful to minimize heat stress through water sprinkle or other means to attain optimal performance of dairy cows.	430
2016	Effect of transportation physical stress of cattle used for beef purpose	Increased number of injury and abrasion and other physical status indicators during transportation indicates higher degree of stress and suffering	431
2017	To detect the effect of heat stress on feed intake, milk yield and composition in lactating dairy cows	The comfortable environmental temperature for dairy cattle ranges 5 to 25 °C and feed intake begins to decline at the ambient temperature of 25-26 °C and drops more rapidly above 30 °C and 40% decline at 40 °C rapidly above 30 °C and 40% decline at 40 °C. The av milk yield (L/d) has reported significantly higher in cool period (14.92 & 19.54) that hot period (12.84 & 15.0). The milk yield and composition are greatly affected by the heat stress during early lactation period.	432
2018	Effect of long distance transport on haematobio-chemical & hormonal	The value of Hb, TEC, TLC, Lymphocyte, Neutrophil and eosinophil varied significantly. The value of TSP, creatinine kinase, triglyceride, Ca, P and alkaline phosphatase significantly differed in cattle	433

### Research findings on cattle fattening

Cattle fattening for beef production have become an income generating important business of the smallholder farmers in Bangladesh.<sup>434</sup> Majority of the cattle fattening farmers involved in cattle fattening just before 3 to 5 months of Eid-ul-Azha, when they sell the animals with profitable price.<sup>435,436</sup> Feeding of urea molasses treated rice straw in beef cattle resulted higher body weight, dressing percentage and also in better carcass quality than feeding untreated straw (Table 10). Farmers are usually used three years old cattle for beef fattening and maximum growth rate between 1.1 to 1.4 years age for a period of 4.5 months.<sup>435</sup> It contributes in poverty reduction, creation of self-employment opportunities in rural areas and animal protein supply. However, the problems and prospects of small scale beef cattle fattening program have been reported as lack of training, high cost of vaccines, limitation of knowledge and inadequate veterinary medical services.<sup>436</sup>

Table 10. Trials of different feed formulations (rations) for fattening of cattle			
Year	Research objective	Major findings	References
1969	To detect the optimum dose of urea with efficient utilization in calves	A mixture of rice polish, wheat bran and til oil cake in addition to rice straw and urea-molasses @ 45g/200lb BW showed better BWG @ 0.929 lb / day / head in comparison to other groups.	437

1977	To detect the effects of a synthetic hormone on the growth and BW in Sahiwal male calves	The ethinyloestradiol (Lynoral <sup>®</sup> Organo) 0.05 mg tablet has been used orally in both the castrated and un-castrated 18 months old Sahiwal calves. The supplemented groups of calves showed significantly higher LWG than non-supplemented groups.	438
1982	To compare efficacy of feeding of urea, lime &/or NaOH treated straw in local calves	It has been concluded that the 5.0% urea (ammonia) treated straw (13g N / kg) found as the best method of feed young cattle as the method has found uncomplicated and urea is the cheapest of the chemicals	439
1983	To compare the benefit of feeding between untreated rice straw and urea or urine treated rice straw in calves	The daily LWG from straw treated with ammonia, using either urea (0.181kg) has been reported as highest in comparison to urine (0.166kg) treated and untreated straw (0.110 kg). Use of urea-treated straw could be best to feed young bulls for benefit.	440
1986	To detect the effect of supplementing 2.0 ml of phosphoric acid in the basal ration in bullocks	Higher DMI and rate of LWG but lower dressing percentages have been reported with phosphoric acid supplemented groups. These findings did not differ significantly but old and emaciated animals showed better performance.	441
1986	To evaluate the profit of cattle fattening program	Feeding of cattle by rice straw, wheat bran, rice bran, oil cake, rice gruel, molasses and green grass resulted net profit of Tk. 50,266/- and 96,606/- from 77 and 99 cattle, respectively.	442
1986	To compare the effect of feeding arail grass and sweet potato leaves in local cattle for 32 days	The average DM intake and BWG have been reported to be higher in cattle fed with arail grass (63.70 kg & 3.58kg) than fed with sweet potato leaves (54.93kg & 2.84kg), respectively.	443
1986	A feeding trial with rice straw and plant leaves	Rice straw + Banana plant with leaves and rice straw + karal leaves fed to two groups of bull calves found not encouraging.	444
1990	To find out the level of protein required for fattening the local bull calves	Protein level 20% below the NRC standard (0.29kg protein/day/animal) could be successfully used for computing fattening ration for local bull calves.	445
1993	To evaluate the effect of hygienic management of the herds	Regular cleaning of the cattle-shed, washing habit, treatment during illness have been reported to be the reasons for good health of the herds.	446
1993	To compare the efficacy of feeding urea-treated straw in the forms of ensiled, soaking & wetting in crossbred calves	Rice straw has been chopped at a length of 5 cm and mixed thoroughly with 5% urea, 15% molasses and tape water and processed as ensiled, soaking and wetting and fed to 3 groups of calves. The ensiled straw showed better performance than socking and wetting process of feeding in crossbred calves.	447
1995	Effect of molasses supplement of UTS feeding on the growth performances	Results showed that the molasses utilized as supplement to UTS (3.0%) at 150g / kg or forages at 100g / kg diet for the profitable beef production from young growing bulls.	403

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1998	To compare the LWG in growing native bull fed with or without wheat bran on straw based diet.	The straw based diet supplemented with 2.0 kg wheat bran/day (30% of the diet) resulted significantly higher LWG 346g/day with FRC 17.57. If the maximum utilization of roughage is the main concern, the optimum BW has suggested as 3kg/day	404
1999	To investigate the cattle fattening program in 26 districts for the target of Eid-ul-Azha of 1998	Cattle have been used for fattening aged between 2-3 years (60.4%) and (60.4%) and 1-2 years (32.2%), bulls (70.4%) as well as heifers (5.2%) for a period of 3-6 months (42%) and 7-12 months (30%). Average buying, selling and net profit (BDT/ cattle) has been reported as 5043, 8360 and 3648, respectively.	448
2001	To detect the effects of supplementing UMS on the LWG in bull calves	Growing bull calves (95.33 kg LW) divided into Gr. A (control) fed with rice straw + green grass and Gr. B (treatment) fed with UMS + UMS + green grass showed higher LWG in Gr. B (169.23kg) than Gr. C (150.17kg) and suggested of feeding UMS for fattening.	449
2002	To compare the LWG in bull calves fed with untreated rice straw (URS) and urea-molasses treated rice straw (UMTRS)	Both the URS and UMTRS groups of calves have also fed green grass and concentrate equally. The UMS feeding has been reported to be beneficial to farmers for cattle fattening. Cattle fattening has increased the use of local feed resources, income and employment opportunity for farmers.	402
2002	To detect the effect of feeding urea and soybean-treated rice straw for fattening of growing bull calves	Feeding of rice straw treated with 4% urea and 4-6% soybean meal with 2 kg green grass and 0.45 kg Til oil cake have been reported successful for the fattening of growing bull calves without any adverse effect on feed intake and growth	327
2002	Effects of feeding untreated straw, urea-molasses straw (UMS) and UMS + wheat barn in growing calves	Average LWG/animal/day has been reported to be 204.17g in untreated straw, 400g in UMS and 418.75g in UMS + wheat fed calves. Thus, the combination of UMS and wheat bran had an influencing effect of LWG in growing calves.	325
2004	To compare the feeding effect between UMS and feeding straw in bull calves for 4.5 months	Control group of bull calves received rice straw + green grass whereas the treatment group received UMS + green grass. Live weight at finishing has been reported as 153.50kg in control and 170.88kg for treated group.	450
2004	To compare the effect of supplement with UMS and MUMS in fattening of bull calves for 5 months	The initial and final live weight of bulls in control (192.26 & 205.81kg), UMS (130.89 & 148.51 kg) and MUMS (168.29 & 187.18kg). The UMS and MUMS feeding in growing bull calves have been reported as beneficial for fattening.	451
2004	To assess economics of cattle fattening	The cost and returns of on-farm cattle fattening by rural farmers have been reported	452
2005	To evaluate the feeding of urea supplemented and urea ensiled straw with or without soybean meal on growth performance of bull calves	Daily weight gain has been reported to be higher in Gr. C fed on 4% urea + 3% soybean meal ensiled straw (0.694kg) than Gr. C fed on 4% urea ensiled straw (0.634kg) and Gr. A fed on 4% urea treated straw (0.509kg). Soybean meal as a urease source with urea treated straw increased the digestibility.	453

2005	To detect the effects of TSP and bone meal supplementation to native cattle	It has been concluded that the dietary bone meal (0.44% P) triple super phosphate (TSP; 0.44% P) supplement in the basal diet increased the final LW 180.33kg and 179.0kg respectively.	454
2006	To evaluate the effects of growth promoters Metafos <sup>®</sup> and Biomix-DB <sup>®</sup> on growing crossbred bulls	Total BWG has been reported to be highest in calves treated with both Metafos <sup>®</sup> and Biomix-DB <sup>®</sup> (45.25kg) than only treated with Metafos <sup>®</sup> (32.50kg) and without any treatment (27.75kg) during 90 days period.	455
2007	To detect the age, fattening period and population size for fattening of cattle	About 56.7% of 2 to 3 years and 36.7% of 1 to 2 years age for the period of 3-6 months and 7-12 months of cattle have been used for fattening in small size by farmers, respectively.	456
2009	To evaluate the feeding of UMS with different level of conc. in emaciated bulls	All the four groups of emaciated bulls received UMS (80%) and green grass (20%) but conc. at 0, 10, 20 and 30% of the DM. The 10% conc. has found effective for economic fattening than 20 or 30% concentrate supplement.	457
2010	To investigate the small scale cattle fattening in the 24 districts in Bangladesh	Most of the small scale cattle fattening farmers (79.1%) fattened their cattle for 3 to 6 months and other in long period. About 63.7% farmers used cattle fattening tablets, 27% used UMS and 51% followed conventional feeding.	458
2010	To evaluate and compare the effect of growth promoter 'Megavit-DB <sup>®</sup> ' in bull calves of Red CC & HF cross cattle	Megavit-DB <sup>®</sup> (Novartis BD Ltd.) @ 17g / animal / day has been supplemented with the daily ration to bull calves. The final LWG has been reported to be higher in both the RC (35.17 ; 26.05 kg) and HF (44.16; 35.21kg) bull calves in comparison to their respective controls. Megavit-DB <sup>®</sup> has suggested for use in cattle fattening.	459
2011	To identify socio-economic characteristics and economic efficiency of cattle fattening	Small scale cattle fattening has been reported to be profitable with a BDT 5559/- cattle. Farmers have used 3 years old cattle for fattening period 4.5 months with urea-molasses straw diet.	460
2012	To survey the use of anabolic steroid and feed additive for cattle fattening	This reported that 58% cattle fattening farmers have been used different anabolic steroids and feed additives for the duration of 3 to 6 months for cattle fattening program.	461
2012	To investigate the existing status of cattle fattening programs of rural farmers	Factors and problems associated with beef fattening and suggestions by farmers have been described to enhance the beef fattening in the district of Dinajpur.	462
2014	A survey of cattle fattening program at rural level using 14 growth promoters in 7 districts of Bangladesh	Majority of the cattle fatteners (60%) have used only straw and 40% have used treated straw of which 28% used UMS and 12% used UTS. In addition, 90% farmers have used growth promoters, of which 78% used vitamin-mineral premix, 8% vitamin-mineral and enzyme premixes (VMEP) and the rest 4% used antibiotic and VMEP for fattening cattle.	463
2016	To detect the effect of Metaphos injection on LWG in fattening cattle	Highest percentage of LWG has been reported with anthelmintic treatment followed by Metaphos (19.79%), Butaphospin (10.06%) and UMS (9.97%) treated cattle. Metaphos has caused LWG from initial 126.93 to 158.25 kg at 70 <sup>th</sup> days of experiment.	464

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2016	To investigate the present status of organic beef cattle production in the district of Sirajgonj	Beef cattle constituted of 12.0% indigenous and 88.00% crossbred cattle, 83.0% farmers used cultivated fodder and 17.0% used cultivated fodder and roadside grass. About 53.0% farmers fattened cattle for 3 months and suggested for organic beef cattle production	465
2017	To detect the effect of age of native Pabna bulls on FCR, digestibility and carcass yield characteristics	Beef cattle farming with native Pabna variety bulls of 25 to 36 months has been reported highest LWG (597g/d) in comparison to 13 to 24 months (519g/d) and lowest in 6-12 months (294g/d). The 25-36 months old bulls has been reported to be more profitable compared to younger bulls.	466
2018	To compare the different breeds and crossbred of beef fattening cattle with their age and attraction of the consumers	The native cattle (52.5%) has mostly used for fattening, followed Holstein cross (25.5%), Sahiwal cross (12.0%), RCC (5.0%) and RCC cross (5.0%), of which native cattle of black and red color have reported highly attractive to consumers during Eid-ul-Adha. The fattening period for 60% cattle has reported as 3-6 months and 30% as 7-12 months.	467
2018	To detect the effect of UMS feeding on feed intake, digestibility and growth of native growing bull calves	The average LWG has been reported to be higher in UMS treated bull calves than that of untreated control calves. It has been suggested that the UMS could be fed for fattening of native bulls because it has enhanced rapid growth and development of the body of animals and earned relatively higher net profit for people.	468
2019	To assess the mixed feeds, feed ingredients & growth promoters in cattle fattening	Approximately 27.5% farmers are dependent on livestock of which 64% practiced fattening for 3 months periods before Eid-ul-Adha. About 86% reared uncastrated males and 59% farmers used steroids (Dexavet, Pednivet, Oradexon, Decason, Paractin, Gludex etc.)	469
2020	To investigate the livelihood improvement of farmers through cattle fattening	The income of the beef cattle fattening farmers' family has estimated to be BDT 11283.33 which has contributed 31.39% of the increased family income. Cattle fattening has been suggested to be the most suitable way to increase the socio-economic status of the farmers	470

### Research on cattle genetics and breeding

Genetics is the science of heredity which is concerned with physical and chemical properties of the hereditary material, how the material is transmitted from one generation to the next and how the information it contains is expressed in the development of an individual. Genetic make-up of animals control their structural configuration and productive abilities either via single genes or by multiple genes situated in different loci. Genes are composed of nucleotide sequences packaged into chromosomes in the nucleus. Milk production is largely affected by a combination of factors namely, genetic make-up in terms of the use of improved breeds selected for milk production, a favorable nutritional environment and improved managerial practices.<sup>471</sup>

Some traits of cattle are under genetic control (heritable) and can be exploited to increase herd profitability. Traits that are economically important and are heritable should be included in the breeding objective of the beef or dairy herds. Variation for economically important traits occurs within breeds and between breeds and some variation can be created by crossbreds. All sources of genetic variation should be considered when planning a breeding program.<sup>472</sup>



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Out of 6.9 million breed-able cows and heifers, HF × L crossbred contributes about 31.29% (Table 11).<sup>37</sup> The milk production performance of HF × L crossbred cows under Bangladesh condition substantially improved (from 5 to 12 (average 10.41) liter/day) gradually over the decades.<sup>474</sup> More than 80% of the breeding bulls used in government AI program are HF × L crossbred.<sup>473</sup> Table 12 shows the summary of the research findings on cattle genetics and breeding of Bangladesh (Table 12).

Year	Major objectives	Major findings	References
1997	To detect breeding profile profiles of bulls & cows	The breeding profiles of Sahiwal bulls and native cows in dairy pocket of Bangladesh have been reported.	477
2002	To estimate the genetic parameters and breeding values of sires and cows	All the variances estimated in native cattle have been reported low compared to both Red Sindhi and Sahiwal. The production in both Red Sindhi and local cattle reported not satisfactory	478
2002	To estimate the heterosis and reciprocal effects of local, crossbred & optimum crossbred system	The native cattle and their crosses are raised mainly for draft animals, then it is recommended that the crossbreds between the local cows and HF bull semen are used for dairy purposes and more than 75% HF blood (LB × HF × HF × HF) is used for beef cattle.	479
2003	Estimation of heterosis	Heterosis for some quantitative traits in dairy cattle have been estimated	480
2005	To detect the genetic status of Red Chittagong cattle (RCC)	The mean No. of alleles per locus of the RCC has been estimated as 6.22 with a total of 56 alleles and frequency varies from 1.61 to 75.93% across all loci and observed and expected hetero-zygosities as 0.594 and 0.649.	481
2007	To evaluate the traits to detect the breeding policy at the CCBS	The traits of 1 <sup>st</sup> lactation length, lactation milk yield and calving interval have been used to detect the cattle breeding policy at CCBS. Suggestions have been made to improve the breeding program in scientific fashion for a steady genetic trend in the herd.	476
2007	To assess the oocyte collection procedure in cows	The intact follicle collection method and CL-absent group ovaries have been reported as suitable for oocyte collection for <i>in vitro</i> nuclear maturation and fertilization of bovine oocytes.	482
2007	To determine the origin and genetic diversity of RCC	Results showed that RCC maintain high genetic variability within the population. Nucleotide sequence divergence showed almost similar age of origination of Indian Zebu breeds as well as RC cattle.	483
2008	To detect the genetic diversity of NBGC	The genetic diversity of North Bengal Grey cattle (NBGC) of Bangladesh based on microsatellite markers have been reported.	484
2008	To detect the heritability & genetic correlation of economic traits of BLRI cattle breed-1 (BCB-1)	The moderate to high heritability along with high genetic correlations with milk yield trait has emphasized continuation of selective breeding program for maximum genetic improvement. This may also be used in planning breeding program for other native cattle germplasm of Bangladesh.	485
2009	To estimate phenotypic & genetic values of RCC for growth traits	The RCC has been reported to have capability for quick response in selection and breeding program for BW improvement. This breeding characteristic would help to establish a local beef breed.	486

2009	To detect the genetic diversity of RCC in Bangladesh	The dendrogram segregated the five population of RCC into two clusters: RCC BLRI and Anwara is one cluster whereas Satkania, Chandonish and Potia made another cluster. The genetic diversity of RCC is relatively higher for a prescribed breed and therefore, have an opportunity to improve them using selective breeding like ONBS.	487
2010	To determine the in-breeding status in a small nucleus herd of RCC	The inbreeding coefficient (IC) of RCC herd has been reported to be 0.019 which is much less than that of other cattle population as well as far below the risky level.	488
2010	To identify the constraints of native cattle genetic resource conservation	Native cattle genetic resource has been reported to be declined day by day due to indiscriminate crossbreeding through AI. This may cause loss of valuable FAnGR, decrease of draught cattle.	489
2011	To estimate the impact of bull performance on progeny early growth and genetic relationships	Records of 4 bulls and 96 of their progeny born 2005 to 2011 with pedigree information have been used to estimate the impact of bulls. Metabolic body weight and residual feed intake of crossbred breeding bull has significant impact on progeny early growth performance.	490
2012	To calculate the heritability and repeatability of standardized milk yield for the RCC	The heritability estimates for TD (test day) and 305-day milk yield have been reported as $0.41 \pm 0.08$ and $0.35 \pm 0.08$ , respectively. The repeatability of 305-day and TDs milk yield estimated as $0.28 \pm 0.12$ and $0.49 \pm 0.04$ respectively using intra-class correlation	53
2012	To estimate regression factors for extending part lactation milk yield from test day record	The best single month for predicting total milk yields by regression method is 5 <sup>th</sup> month's test day record with correlation coefficient of 0.81 with complete yield. The correlations of those monthly records with complete record have been reported as 0.74 to 0.81	491
2012	To estimate genetic trends of some dairy traits of seven genetic dairy cows	The high genetic variability of birth weight, lactation yield, fat and SNF% have been reported for a good opportunity for genetic improvement with these selected traits in cows.	492
2012	To predict breeding values of dairy sires using individual daughters performance	The heritability values have been estimated as 0.27% for birth weight, 0.45% for lactation yield, 0.37% for fat and 0.46% for SNF. The high genetic variability indicates a great scope for genetic improvement.	493
2013	To detect the seasonality of reproduction and to estimate reproductive efficiency of RCC	The month of the year had significant effect on both estrus and calving but not for CR. No significant effect of season with estrus or CR or calving but numerically highest estrus (36%) and CR (38%) in summer and calving in winter (36%) have been reported.	494
2013	To assess the status of cattle breeding system at rural levels	Breeding status of estrus cattle at smallholder levels have been reported as signs of estrus (prominent 99.64% & silent 1.36%), type of service (natural 38.94% & AI 61.06%), source of semen (Govt 25.0%, BRAC 13.63% & BAUI center 61.36%), system of AI (cows at AI Center 60.0% & inseminator at home 40.0%), bull used in natural service (native 58.87% & crossbred 41.13%) and genotypes used in AI (HF cross 43.07%, Sahiwal 14.6%, native 39.41% & others (2.92%).	495
2013	To estimate the genetic parameters of Holstein crossbred dairy cows	The mean calving interval has been reported to be 442.59, 449.86 and 457.88 days in H × L, H × SL and H × S1 × L crossbreds, respectively. The H × L genotype has been reported most efficient among the 3 genotypes.	496
2015	To select the dairy breeding bulls based on their progeny performance	Out of 5 HF cross-bred candidate bulls, of which two have been found promising due to their positive breeding values based on 100-day milk yields of 199 first calving daughter.	497

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2016	To find out the reproductive performance of native cows with using Brahman crossbred bull	The overall 63.11% CR and 90.96% calving rate of native cows breeding with Brahman semen have been reported. Satisfactory reproductive performance of indigenous cows has been reported by using frozen semen of Brahman crossbred bull	498
2019	To estimate ratio factors and regression coefficient to extend milk yield for 300 days in RCC	Results showed that both ratio factors and regression coefficients estimated have been suggested to be used more accurately to estimate 300 day milk yield for the indigenous cattle including RCC in Bangladesh	499
2019	To estimate the genetic evaluation of RCC	The high estimates of heritability reported except average daily milk yield indicates that the genetic improvement of these traits can be achieved through selection and breeding in RCC	500
2020	To estimate the genetic (heritability & correlation) and breeding value of Brahman crossbred cattle	The high magnitude of heritability estimates for growth traits reported indicates that the selection can be highly effective in changing growth traits in Brahman crossbred cattle. Strong genetic and phenotypic correlation of growth trait indicated that selection for one trait will improve the others simultaneously	501

### Semen collection and crossbreeding by using artificial insemination

High reproductive performance is an essential requirement to ensure maximum food animal production and satisfactory economic return. The AI promotes genetic and economic gains through the use of superior genetic bulls. However, implementation of AI programs based on estrus detection is hampered mainly by post-partum anestrous and estrus detection failure. The timed artificial insemination (TAI) has been applied routinely in the reproductive programs on farms. TAI protocols are designed to promote control of both luteal and follicular function, permitting the TAI with satisfactory pregnancy per AI. Crossbreeding is the mating of individuals from different lines, breeds or populations with the objectives (a) to utilize the different additive genetic levels between breeds to generate offspring with better economic ability caused by new combinations of additive genetic components and (b) crosses between pure lines / breeds express heterosis. Crossbred cattle are more robust and economically efficient compared with the parental breeds.<sup>502</sup>

The cattle of the then East Bengal was mainly indigenous type (*Bos indicus*) with low productive potentiality and this situation was somewhat improved by introduction of improved variety of *Bos indicus* Hariana bull from northern India in limited regions by the British Viceroy Lord Airlith Gow in 1936. After independence from British Raj in 1947, second effort was made to upgrade the native cattle by importing Sindhi and Sahiwal bulls from West Pakistan to East Pakistan for natural services.

Dairy cattle improvement program in Bangladesh was started in 1958 by DLS with AI program which was strengthened in 1975-76. However, the absence of following the proper process of improvement like registering, recording and others, the government has not achieved any marked over this long period of 55 years.<sup>503</sup> The dairy cattle improvement program has been launched with the aims to improve the indigenous cattle through crossbreeding program by using both tropical bulls (Sindhi and Sahiwal) and temperate bulls (Holstein-Friesian and Jersey). Accordingly, in 1973, some Friesian and Jersey bulls were imported from Australia and ultimately crossbreeding program by using artificial insemination program started rapidly in Bangladesh.

DLS was started AI for dairy cattle improvement in the 1960s, BRAC was started cattle breeding program with AI services using government liquid semen in 1985 in Manikganj district using trained technicians. Up to 1996, BRAC worked in collaboration with DLS for a decade for AI. But this partnership discontinued due to management, non-cooperation and lack of control over AI volunteers by BRAC. BRAC has established its own bull station and started actual frozen semen production and started its AI program in 2000. This NGO have trained 2523 AI technicians and operating AI services in 61 districts (440 upazila). This organization have produced 13,00,000 doses frozen semen (including previous frozen semen stock) and inseminated 13,24,000 cows throughout the country.<sup>504,505</sup> Currently DLS, BRAC, Cooperative Dairy Production System and other organization have been working in crossbreeding program in Bangladesh. Accordingly, huge number of inland research reports has been published on semen and AI services in cattle in Bangladesh (Table 13).

Table 13. Summary on research reports on the collection semen from breeding bulls and artificial insemination (AI) services under field conditions in Bangladesh			
Year	Major objectives	Major findings	References
1964	To assess the use of AI in indigenous cows	Reported 60.52% conception rate (CR) of AI by first insemination in East Pakistan indigenous cows	6
1968	To detect the influence of feeding on semen production in bulls	Low level of feeding has been reported to be associated with the delay the onset of semen production by a few months in compares to moderate and high levels of feeding in bulls.	506
1968	To assess bull semen	Repeatability of semen characteristics of yearly bulls have been reported	507
1969	To detect the major causes of AI failure in cows	Five major causes have been reported to be associated with the failure in AI in cows which include (a) failure of ovulation, (b) failure of an ovum and spermatozoa to meet, (c) failure of fertilization, (d) failure of implementation and (e) embryonic mortality and abortion.	508
1971	To detect the CR by AI based on psychic conditions in cows	The CR by AI has been reported to be associated with psychic condition of the estrus cows. Highest CR has been recorded in quiet (62.55%) in comparison to moderately nervous (58.59%) and nervous (46.52%) cows.	509
1974	To evaluate the dilutors and extender for storage of semen	Extenders glucose citrate (sperm motility (SM) up to 4 <sup>th</sup> day 25%), Cornell University-16 (SM up to 4 <sup>th</sup> day 39%) and egg yolk citrate (SM up to 7 <sup>th</sup> day 25%) have been reported.	510
1975	To assess the sires	Assessment of dairy sires by contemporary comparisons have been reported	511
1982	To determine the size of head and tail length of bull spermatozoa	Average head length, head breadth and tail length of bull spermatozoa have been reported to be 9.538, 4.692 and 58.578 $\mu$ , respectively.	512
1982	To differentiate the X and Y chromosome and their effect	Dimorphism of sperm cells with X-chromosome bearing sperms being heavier than Y-bearing ones. Centrifuged spermatozoa from the top as well as bottom of the layer need to be inseminated for actual sexing of the calves.	513
1985	To detect the seasonal and genetic influence on semen characteristics	No significant seasonal effects on volume and initial motility of L $\times$ HF and SL $\times$ HF bull semen whereas the highest semen concentration during winter than summer have been reported.	514

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1990	To compare the SM and EYC diluents for preservation & CR of semen	The quality of the preserved semen has maintained better in soybean milk (SM) than in egg-yolk citrate (EYC) for 6 days. The conception rate (CR) of the AI has found higher with semen preserved in SM (68.1%) than EYC (64.7%).	515
1990	To evaluate the imported deep frozen Sahiwal semen in fertile zebu cows	An overall 62.51% CR has been reported in zebu cows with imported deep frozen Sahiwal semen with highest CR in first AI (63.53%) in comparison to 2 <sup>nd</sup> (51.11%) and 3 <sup>rd</sup> (50.0%) AI. Significantly higher CR at the mid-cycle (69.69%) than early (58.8%) and late (33.8%) cycle of AI.	516
1992	To detect the seasonal effect on CR / non-return rates in zebu estrus cows	The spring (Feb-March) has been reported to be the best season for fertility (AI) of cows and heifers in both the dairy farms (CR 62.12%) and smallholder farmers (CR 84.97%) but lowest during rainy seasons.	517
1993	To evaluate the impact of AI to upgrade the native cattle at rural level	The use of AI has resulted 71% crossbred cattle at the rural levels under the Milk-vita cooperative society. The author has suggested five criteria to improve the cross-bred cattle at rural levels	518
1993	To evaluate the breeding soundness of 12 AI bulls	An average $37 \pm 1.62$ cm scrotal circumference of bulls with significant difference in volume of ejaculates, sperm concentrations/ mm <sup>3</sup> , mass activity and motility among bulls have been reported.	519
1993	To assess the status of AI and cost of local and imported semen	The AI technique has introduced in Bangladesh in 1958. Currently the AI program has been operating through 23 AI centers, 416 sub-centers and 425 points covering all the 64 districts.	520
1994	To find out the effective genetic group, season & age of bull on the semen characteristics	Highest volume of ejaculate has recorded in $\frac{1}{2}$ SL $\times$ $\frac{1}{2}$ HFcross (8.46 ml) with lowest in $\frac{1}{2}$ SL $\times$ $\frac{1}{2}$ SL (5.15ml). Highest concentration of sperm has recorded in 100% Sahiwal (1234.77 million / ml) and $\frac{1}{2}$ SL $\times$ $\frac{1}{2}$ SL cross bred (1125.44 million/ ml) bulls. No significant seasonal effect but age has effect on volume and sperm conc.	521
1994	To detect the reasons of adopting and non-adopting AI at smallholders farmers' levels	Out of 960 smallholder farmers, 640 (28%) adopted AI but 320 (23.0%) non-adopting farmers. The reasons for non-adopting AI included high calf mortality (46.86%), non-conception (38.84%), availability of local bulls (38.75%), distance of AI points (37.19%), high fee for AI (19.69%), bothering job (20.0%), lack of breedable cows and feed problem (11.25%).	522
1994	To detect the seasonal influences on the AI with Sahiwal imported frozen semen from NZ	Out of 680 estrus cows, significantly higher numbers has been inseminated in spring (n=208) and lowest in monsoon (n=100) but significantly higher non-return rate (NRR) in winter (89.47%) and low in monsoon (86.47%) . Highest number of calves has borne in winter (n=94) and lowest in summer (n=73) season.	523
1996	To evaluate the different crossbred bulls for semen characteristics	The predictions has been reported to be highest in $\frac{1}{4}$ Local $\times$ $\frac{3}{4}$ Friesian, followed by $\frac{1}{4}$ Friesian $\times$ $\frac{3}{4}$ Sahiwal, Sahiwal, $\frac{1}{2}$ Local $\times$ $\frac{1}{2}$ Friesian, $\frac{1}{2}$ Local $\times$ $\frac{1}{2}$ Friesian, $\frac{1}{2}$ Sahiwal $\times$ $\frac{1}{2}$ Sahiwal $\times$ $\frac{1}{2}$ Friesian and $\frac{1}{2}$ Sindhi $\times$ $\frac{1}{2}$ Sahiwal.	524
1997	To evaluate the semen of four imported Sahiwal bulls from Pakistan	Semen has been collected from each of four bulls at the same age (3-4 years) twice a week and 11480 cows have been inseminated with these semen. Bull-wise breeding performance in terms of semen values, non-return rate, calving rate, pre-natal loss and calf mortality up to 3 month have been evaluated.	525
1997	To assess bull and semen	Reported that the semen of the seminal vesiculitis affected bulls have been routinely used for artificial insemination	526
1998	To detect the effects of ambient temperature on bull spermatozoa	Ejaculates harvested at a temperature of 19 to 25 <sup>0</sup> C had a lower (1.7%) abnormal acrosome bearing spermatozoa than that collected at >25- 30 <sup>0</sup> C (5.4%) and > 30-33.5 <sup>0</sup> C (4.9%).	527

1998	To detect the hygienic status of quality of bull chilled semen used for AI in cows	The chilled (4-7 °C) semen has retained good proportion of normal, motile spermatozoa for 2 days at the AI center but not after transport- action to sub-centers that contained live bacteria in an AI dose. This indicates contamination of semen during collection and processing.	528
1998	Factors of AI to detect fertility of cows	The fertility of cows has been reported to be significantly affected by the site of semen deposition, skill of inseminator and time of onset of estrus.	529
1998	To assess the status of AI in the field levels	172 farmers of 27 Upazila inseminated their cows have been evaluated. Insufficient number of AI center, inadequate knowledge of heat detection, unscientific transfer and storage of semen have been identified as major drawback of cattle production by AI.	530
1999	To evaluate the semen between native cross-bred bulls and imported Friesian bulls	The imported bull semen possessed better post-thaw sperm motility(60% vs 45%), more motile spermatozoa / cow dose ( $14.7 \times 10^6$ vs $9.9 \times 10^6$ ), higher proportion of spermatozoa with normal acrosome, mid-pice and tail (83.0% vs 61.4%) and higher service CR (59.9%) than with the semen of native bulls (52.9%).	531
1999	To detect the effects bull quality and type of semen on the first service CR of AI	Cow inseminated with good bull semen (55.2%) conceived at a higher rate than those inseminated with poor bull semen (37.1%). Higher CR has been reported with frozen semen (58.2%) than that for chilled semen (35.9%). High fertility bulls could be used for AI	532
1999	To evaluate the storage of frozen semen straw in 2-liter LN	The frozen semen straws has been reported to be stored in 2-liter liquid nitrogen (LN) container with acceptable quality for 10 days without loading of LN under field conditions.	533
1999	To identify the risk factors associated with service per CR with AI in dairy cows	A total of 6052 AI records of CCBSDF and 525 cows of AI Center, Mymensingh have been evaluated for CR. The minimum service per CR has been reported in spring (1.68), on 5 <sup>th</sup> parity (1.77), in village condition (1.63) and in the month of December (1.64).	534
2001	Size of head and total length of spermatozoa	Average head length, head breath, head shape and total length of bull spermatozoa have been reported as 10.12, 5.05, 2.0 and 73.98 $\mu$ respectively.	535
2001	Semen characteristics of bulls	Phenotypic variation and repeatability of semen characteristics of bulls have been evaluated.	536
2001	To evaluate the individual bull and season factors affecting semen production	Semen parameters have been reported to be affected with individual AI bulls. Season has significantly influenced the volume and the sperm concentration. Highest semen volume has obtained in winter (8.34 ml) and lowest in summer (7.02ml)	537
2002	To evaluate the quality & fertilizing capacity of locally produced chilled & imported frozen semen	Quality of imported frozen semen has been reported better than locally produced chilled semen in respect of motility and sperma tozoa with normal head. Higher CR of imported semen (57.33%) has been reported than locally produced chilled semen (45.33%).	538
2002	To investigate the effects of breeding groups and environmental factors on conception rate (CR)	The highest CR has been reported in heifers (52.11%), spring season (51.30%) and inseminated between 8 to 14 hours after onset of estrus (53.24%). The interaction effects of PB $\times$ HF dams $\times$ SL sires (52.75%), SL sires $\times$ spring (52.17%) and PB $\times$ HF dams $\times$ winter (52.21%).	539
2002	To detect the age & season on BW, SC, libido & ejaculates interval in bulls	The age group of 3 to 4 years and summer season have been reported to have better influence on body weight (BW), scrotal circumference (SC), libido and time required between two ejaculates of Sahiwall bulls at the CCBSDF, Savar	540

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2003	To evaluate the success of AI & service required per conception of cows	The CR of AI has been reported to be 55 to 73% during 1998-99 and 55-66% during 1999-2001 in Pahartali district. The service has required per conception varied from 1.3 to 1.8.	541
2003	To evaluate the quality of semen in different genetic groups of bulls	Highest sperm conc. (1332 million/ml), motile sperm/ ejaculate (5621 million / ml, motility (64%) and no. of semen collection / month (5.84) with an interval of < 6 days have been reported in 100% Sahiwal and 50%SL × 50% HF bulls	542
2003	To assess semen characteristics and AI in cattle	Effects of breeds and age of bulls on semen characteristics used in AI in cattle have been reported.	543
2004	To compare the semen quality of different genotypes of bulls	Among the seven genotypes of bulls, only Friesian bulls produced the largest volume of semen (14.26 ml), mass movement (4.87 grade) and forward movement (61.29%) of sperm. Bulls of 4-5 years of age, 600-700 kg BW of bulls and summer produced better quality semen.	544.
2004	To compare the quality of bull semen preserved as homo-and hetero-spermic forms	Spermatozoa of three different breeds of bulls (HF, RCC & SL) have mixed in number and preserved for 3 days. The hetero-spermic semen has found better preserved in terms of mass motility, normal and live sperm % compared to homo-spermic ones.	545
2004	To compare the relative efficiency of homo-and hetero-spermic AI to fertility judged by conception & calving rate	Spermatozoa of HF, RCC and SL have been mixed in equal number and preserved for 3 days and inseminated at different days. The hetero-spermic AI did not show any significant superiority in conception and calving rates in cows compared to homospermic AI. However, no risk has been reported by using hetero-spermic semen in AI.	546
2004	To evaluate the bull performance through semen quality and 30-day non-return rate	Data of 245 ejaculates and 12750 services of 5 Sahiwal bulls for five years have been evaluated. High variability in the potentiality of semen quality and fertility of bulls have been reported. The evaluation of breeding bulls on the basis of semen quality and herd fertility has suggested.	547
2004	To detect the effect of genetic groups of bulls on sperm and CR	Minimum sperm abnormalities has been reported in pure breed bulls than crossbred bulls, and 100% Local, 100% Friesian and ½ SL × ½ HF bulls have reported better CR in cows.	548
2004	To evaluate the adoption status of AI	Approximately 47.17% households have been rearing cattle at village level of which 44.0% smallholder farmers adopted AI technique for breeding their cows.	549
2005	To assess the semen quality at chilling condition	The semen quality has been reported to be decreased in chilling condition with the advancement of preservation and remained suitable for use up to day 2 as judged by motility and morphology.	550
2005	To evaluate the semen parameters of breeding bulls	Significantly highest semen volume per ejaculate, % individual in motility (progressive) and sperm concentration have been reported 87.5% HF × 12.5% L and lowest in 50% HF × 50% L bulls.	551
2005	To evaluate the spermatozoa of six genetic groups of bulls	Genetic groups of 100% Friesian and 50% SL × 50% HF crossbred have been reported to have better performance of the dimensional characteristics of spermatozoa	552
2006	To evaluate the chilled and frozen semen by AI in cows	Results suggested that the 78.54% NRR of cows at 60 days after 1 <sup>st</sup> AI under field condition has suggested a good practice to discard poor fertility semen, type (chilled & frozen), quality of bull semen and sources of semen.	553
2007	To evaluate the performance of breeding bulls	Reported that 100% Friesian breed had better phenotypic performance and summer favored good performance	554

2007	To evaluate the semen	The semen and non-return rate of bulls have been evaluated in AI	555
2007	To assess AI in cattle at rural farmers' level	The adaptation condition of rural farmers toward AI in cattle the district of Sirajgonj has been reported	556
2008	To evaluate frozen semen	The frozen semen of Red Chittagong cattle has been evaluated.	557
2008	To evaluate the performance of breeding bull based on semen quality	Evaluation of the bull performance based on semen quality and 60 days non-return rate (NRR) showed that HF cross bulls ranked top and RC bulls reported inferior among the bulls tested.	558
2008	To evaluate the breeding bulls based on physically and semen quality	The HF × L crossbred bulls produced better quality semen than other genotypes of breeding bulls based on semen volume, sperm motility, sperm concentration and % of dead sperm.	559
2009	To detect the relationship between scrotal circumference and semen parameters	Scrotal circumference has been reported to be correlated with semen volume, sperm concentration and number of spermatozoa per ejaculate. Results showed that crossbred bulls aged 18 months or more with scrotal circumference > 30 cm, yielded good quality semen.	560
2010	To assess the semen production of different breeds of bulls at CCBS and their performances	Approximately 1.7 million doses of semen have been produced by the 145 bulls of nine different breeds during 2008-2009. The HF cross cows has been reported highest milk yield (7.4 L/d) in comparison to other cross-bred under field conditions in Bangladesh.	561
2011	Risk factors associated with pregnancy rate with 1 <sup>st</sup> AI	The pregnancy rate of L × HF crossbred (34.9%), first parity cows(37.3%), summer season (43.1%) and less skilled AI technician have been reported as the risk factors for low pregnancy rate at first AI in cows.	562
2012	To find out the physical and chemical properties of different breeding bull semen	Highest ejaculate volume has been reported with SL × HF crossbred (12.9 ml) and lowest volume in L × HF (7.4 ml). The ejaculate volume, concentration, pH and motility of sperm have substantially influenced by freezing and breed type. Better semen characteristics have been reported in Sahiwal followed by local and SL × HF crossbred bulls.	563
2012	To evaluate the imported semen of Brahman bulls in native cows to produce graded calves	The 233 Brahman grade-1 calves (127 male & 106 female) with average birth weight 22.25kg & 20.33 kg, daily weight gain of 547.42g & 470.34g and yearly live weight of 222.07 and 191.76 kg respectively have been reported. This cross-bred may generate to produce beef cattle.	564
2012	To detect the fertility status of female RCC	The service per conception required 1.4 AI with an overall 85.0% pregnancy rate in RCC which is encouraging as compared with others.	565
2013	To evaluate the effect of α-tocopherol in preservation of chilled semen	Semen treated with 2 mg/ ml α-tocopherol (50% BASF, Germany) has been reported to be best for improving keeping quality of chilled bull semen up to 5 days. It acts by preserving cell membrane damage from lipid peroxidation.	566
2014	To compare the provision of the existing AI-SDS among public, private autonomous institutions to smallholder farmers	The existing AI-SDS (service delivery-system) from public, private and autonomous organizations are not in the line with the expectation al of the farmers. The relatively lower incentives, higher transaction cost, poor network coverage, institutional barrier to make access to the farmers' complain about their service – all these make inefficient.	567
2014	To detect the risk factors associated with CR of AI in cows	Cows (n=184) have been inseminated between 6-12 hours of onset of heat with AI by using frozen semen resulted an overall 54.9% CR. Higher CR in cows has been reported in spring (78.9%) than summer (29.8%), winter (72.1%) and rainy (35.7%) seasons. Higher CR has been reported in 1 <sup>st</sup> and 2 <sup>nd</sup> AI (89.7%)	568

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2015	To detect the risk factors associated with CR of AI in cows	Breed, parity and number of service have been evaluated in 350 inseminated cows. CR has reported comparatively higher in Local (69.23%) than SL (67.92%) and HF (57.22%). The 3 <sup>rd</sup> parity cows showed highest CR (79.63) than other parities. Higher CR reported in 1-2 services (65.0%) than $\geq 3$ services (50.0%)	569
2015	To evaluate the factors affecting the rates of pregnancy, calving and peri-parturient disorders in crossbred heifers	Crossbred heifers (n = 101) inseminated with Sahiwal (n = 61) and Friesian (n = 40) semen resulted pregnancy (54.1% & 47.5%), calves borne (49.9% & 35.2%) and peri-parturient disorders (23.5% & 50.0%), respectively. The rates of pregnancy, calves borne and peri-parturient disorders did not differ significantly with age, BW, BCS and source of semen.	570
2015	To detect the risk factors associated with fertility and pregnancy rate in cows due to first AI	Breed, parity, BCS, LW, milking, feeding and open period have been evaluated as risk factors of pregnancy rate in inseminated 450 cows. Highest pregnancy rate has been reported in 5 <sup>th</sup> (62.5%) and 6 <sup>th</sup> (75.0%) parity than others, BCS between 2.1 - 4 (34.5%) than < 2 (0%) and > 4 (25%), lactating (39.3%) than dry (22.5%) period.	571
2015	To detect the effect of ejaculation frequency on semen characteristics and sperm output	Ejaculation of Brahman $\times$ Local F <sub>1</sub> crossbred breeding bulls at 4 $\times$ weekly yielded 1.6 times more motile sperm output per week than ejaculation at 2 $\times$ weekly. The scrotal circumference reported highly correlated with semen volume and total progressive motile sperm per ejaculate	572
2016	To evaluate the AI and factors affecting CR	The CR of different genotypes varied from 59.13 to 63.65% with highest CR in summer and winter and lowest in rainy season. The CR associated with semen quality & preservation, time of AI, breeds and season	573
2016	To detect the risk factors associated with pregnancy rate in AI inseminated cows	Cows (n = 224) have been inseminated between 12 to 18 hours from onset of estrus, from which 59.29% become pregnant. Age, breed, parity and bull semen have been evaluated as risk factors, of which 4 years (70.27%), local (69.07%), 3 <sup>rd</sup> parity (67.74%) and 62.5% SL bull semen showed highest pregnancy rates.	574
2017	To review the status of existing CBBPs, their prospects & limitations	The sustainable community based breeding programs (CBBPs) has reported as a major challenge due mainly to short-term funding, lack of commitment and rapid urbanization and self-sustained program is not sustainable. Coordinations of the research institutes, govt livestock department, cooperatives and agribusiness agent would be required for sustainable breeding program.	575
2017	To assess the motility & velocity of ejaculates sperm of Brahman crossbred breeding bulls	The computer assisted sperm analyzer (CASA) with android vision software has been used to assess the motility and velocity of ejaculates sperm. The CASA has been found effective for a quick and objective analysis of motility and velocity in Brahman crossbred bull semen.	576
2018	To compare the performance of breeding bulls based on libido, semen quality and fertility	The HF crossbred breeding bulls have been reported to be significantly higher libido and better sperm quality than that of Brahman and RCC. Results also showed that the libido, semen quality and fertility are linked together	577
2020	To evaluate the frozen semen quality of imported pure HF and Sahiwal breeding bulls	Frozen semen quality of HF breed has been reported better than Sahiwal breeding bulls but no difference of non-return rate between HF (64.19%) and Sahiwal (64.71%) bulls. Suggested to use frozen semen of both the breeds for genetic improvement of cattle	578
2020	To characterize, compare, estimate of heritability and genetic & phenotypic correlations of semen of three genetic bulls	The maximum sperm conc ( $\times 10^6$ /ml) has been reported for local (1516.59), followed by Brahman (1380.38) and lowest HF (1105.03). The heritability for semen production varied from 0.39 to 0.51 (BG), 0.36 to 0.48 (HF) and 0.35 to 0.44 (LG) bulls. Brahman genotype ranked 1 <sup>st</sup> in comparison to other genotypes.	579

### **Milk-vita (Bangladesh Milk Producer's Cooperative Union Limited= BMPCUL)**

Milk vita, the trade name of BMPCUL started dairy business based on genetic improvement of dairy cattle through AI services of their cooperative farmers in 1972. In addition to semen, Milk-vita has periodically imported Sahiwal bulls from Pakistan (1991) and four Friesian and three Jerseys bulls from Australia (2002). Initially, Milk-vita started to produce and use liquid semen, later they shifted towards producing frozen semen.<sup>503</sup>

### **Lal Teer Livestock Limited (LTLL)**

The LTLL has started cattle and buffalo improvement program since 2009. They are producing semen from locally produced environmentally supported proven bull at different blood levels crossing with the imported frozen semen of Holstein, Frisian, Jersey and Sahiwal breeds and distributing / marketing it through AI services for increasing milk production throughout the country.<sup>503</sup>

### **Pran Dairy**

The Pran Dairy has started dairy breed improvement program with frozen semen and AI services imports from World Wide Sire, USA.

### **Gentech International**

The Gentech International has started dairy breed improvement program with frozen semen and AI services imports from World Wide Sire, USA. They have also started to develop AI inseminator to provide training to the local field participants.

### **BAU AI services**

Two departments of the BAU are also involved in AI services to the farmers in and around the university areas. The frozen semen is originated from the government AI Laboratory while liquid seem is produced by their own bull studs.

### **Central Cattle Breeding Station & Dairy Farm (CCBSDF)**

Research on semen production and their uses for AI have been conducted at the CCBS, Savar during 2008-2009 on 145 breeding bulls of various breeds and breed combinations.<sup>561</sup> Approximately 1.7 million doses of semen were produced from these bulls (Table 14).

The AI is the first generation reproductive biotechnology that has made a profound contribution to the genetic improvement as well as recognized breeding tool of the cattle.<sup>580</sup> The majority (58.0%) of the smallholder farmers have reported to faced medium problems while 39.0% with high and only 3.0% with low problems in adopting AI in their cattle. The inseminator problem and heat stage have been recognized as the most critical problems.<sup>580</sup> Crossbred cattle contributes about 24.0% of the 6.9% million breedable cows and heifers and HF × L crossbred cow's milk production performance considerably improved over the decades.<sup>581</sup> Approximately 87% smallholder dairy farmers have used AI for breeding cows in Rangpur.<sup>582</sup> Cows are inseminated 76% by AI and 24% both AI and natural services in Jossore.<sup>583</sup>

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Table 14. Breeds of bulls at CCBS, Savar and uses of semen for AI<sup>561</sup>

SN Breed	No. of bulls	Dose of semen (000')	SN Breed of bull	% used in AI
1. Friesian (F)	02	039.6	1. Friesian (F)	54
2. Sahiwal (SI)	10	-	2. Friesian (F) × Sahiwal (SL)	17
3. Local (ND)	08	116.1	3. Sahiwal (SL)	10
4. RCC	02	005.0	4. Friesian (F) × Red Sindhi (RS)	09
5. SL × F	30	-	5. Friesian (F) × Pabna (P)	03
6. L × F	93	1556.9	6. Red Sindhi (RS)	03
7. L × F × F	-	-	7. Red Sindhi (RS) × RCC	02
8. SL × F × F	-	-	8. Friesian (F) × Jersey (JS)	01
-	-	-	9. Red Sindhi (RS) × Sahiwal (SL)	01
<b>Total:</b>	<b>145</b>	<b>1717.6</b>	<b>Total</b>	<b>100</b>

- = Data not available

### Conception rate (CR) of AI in cattle

The CR plays a major role to achieve a successful reproductive performance of dairy cattle. However, the successful outcome of an AI is a combination of both bulls and cows fertility-linked factors. The AI technique has been used from more than 50 years in Bangladesh and this program is extended every year. The first service CR for particular group can be determined by the number of heifers or cows given first service multiplied by 100.  $CR = \frac{\text{No. of pregnant}}{\text{Total No. of cows inseminated}} \times 100$ . Pregnancy rate is the percent of cows eligible to be bred that actually get bred that become pregnant multiplied by the CR of those inseminations in any 21-day (average length of a cow's estrus cycle) period of time. Table 15 shows the conception rate under different breeding methods in heifers and cows in Bangladesh. Research findings on the factors associated with the conception rate have been reviewed (Table 16)

Table 15. Conception rates under different breeding methods with services in heifers and cows

SN Breeding methods & results of service	No. of cattle	Conception rate (%) with services					Ref. No.
		1 <sup>st</sup> service	2 <sup>nd</sup> service	3 <sup>rd</sup> service	4 <sup>th</sup> service	5 <sup>th</sup> service	
<b>A. Breeding methods</b>							
1. Natural service	237	62.45	06.75	05.91	04.64	79.75	584
2. AI with liquid semen	802	55.86	48.31	41.53	39.62	38.46	584
	323	25.08	18.58	12.69	02.48	58.83	584
3. AI with frozen semen	325	42.15	14.46	05.85	02.46	64.92	584
<b>B. Results of service</b>							
1. Live calves borne	802	410 (51.1)	151 (42.7)	69 (37.7)	39 (36.8)	23 (35.4)	585
2. Abortion/stillbirth	802	038 (8.5)	020 (11.7)	07 (09.2)	03 (07.1)	02 (08.0)	585

Table 15 shows that the CR and calving rate reported highest after first AI services (55.86% and 51.1%) respectively, reduced gradually with the increasing the number of services and lowest after 5<sup>th</sup> AI 38.46% and 35.4%, respectively.

Table 16. Factors associated with conception rates in cattle			
Year	Objectives	Major findings	References
2003	To evaluate the CR of AI in cattle	The overall average CR of 59.0% with varied between 55 - 73% with an average of 1.7 number of service per conception	541
2004	To evaluate the effects of genetic, environmental and their interactions affecting CR in cattle	Highest CR in native (46.14%) than HF × L crossbred cows (35.39%), up to 2 <sup>nd</sup> parity (46.8-52.57%) then decreased (50.27-25.57%), 60.26% when inseminated between 11-14 hrs on the onset of estrus, during spring (53.07%) than summer (37.89%) and winter (39.42%).	586
2010	To identify factors affecting the CR in RCC	The average overall 63.85% CR in RCC which can be increased by taking different measures like AI at observing clear mucus and 10-14 hours after the onset of estrus, thawing of straw at 37 °C for at least 10-12 seconds, heating of AI devices, service at docile condition, placement of semen at the body of the uterus and avoid cross-breeding of RCC with exotic blood to ensure protection from reproductive disorders like difficult calving and retained placenta.	587
2010	To determine the PR and No. of services / pregnancy in RCC	The overall average 65.8% PR with 1.4 services per pregnancy have been reported in RCC. The NRR varied from 53.1 to 70.6% with an average of 63.9%.	588
2011	To determine the factors that limit PR of first AI in cows in Sirajgonj district	The overall average 57.3% PR and 42.7% first AI PR with an average overall 1.7 number of AI required for early pregnancy. The HF × L cross (34.9%), first parity (37.3%), rainy (34.5%) and less skilled AI technician (38.6%) have been reported as risk factors for low PR at first AI in cows	562
2012	To determine the affecting the first service CR of cows in smallholder dairy farms	The overall CR has been reported to be 50.7% which varied between 43.4% and 58.6% based on AI technicians. BCS, heat detection signs, months of AI and their interactions had great effects on 1 <sup>st</sup> service CR in cows. AI based on mounting activity, genital discharge and restlessness yielded CR of 53.6%, 48.8% and 50.1% respectively	589
2012	To introduce and adopt two different estrus synchronization protocols and their effects on pregnancy rate in local and cross-bred heifers	Heifers of group A treated with GnRH at first day followed by a single dose of PGF <sub>2</sub> α at day 11 and GnRH at the day of AI, whereas heifers of group B treated with GnRH, two dose of PGF <sub>2</sub> α at day 11 day apart and GnRH at AI. The overall pregnancy rates have been reported as 33.3% and 36.6% in groups A and B respectively. In addition, the higher pregnancy rate in treated groups (35.0%) in comparison to control (28.3%) groups.	590
2014	To determine the CR of cows & heifers inseminated artificially	The cows have been inseminated between 6 to 20 hours of onset of estrus and an overall 54.9% CR has been reported with higher in HF × L cross (62.3%) than local (52.95) and Sahiwal cross (40.0%)	568
2015	To determine the effects of some factors on first service pregnancy rate (PR)	Overall PR 52.6% with highest in 3 to 5 years of age (56.1%), parity 1 to 2 (57.4%), 2 to 5 liter yield (62.1%), fed green grass, straw and concentrate (63.5%) than only fed straw (38.5%), BCS 3 to 4 (58.0%) than 1.5 to 2.0 (35.0%), inseminated 6 to 12 hours (58.8%) than 13 to 24 hours of onset of estrus (40.4%) in cows	591
2015	To evaluate the factors affecting pregnancy rate, calving and post-parturient disorders in heifers received AI	The overall average 51.5% pregnancy rate, 45.5% disorders and 32.6% peri-parturient disorders have been reported in heifers received AI. The use of Sahiwal bull semen resulted 54.1% PR with 49.9% calving rate whereas HF bull semen resulted 47.5% PR and 35.2% calving in heifers	570

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2015	To determine the factors influence the CR in dairy cattle at first service in char areas of the northern districts	Higher CR between 2.5 to 3.0 years (68.0%) than 4.5 to 5.0 years old cows, cows provided improved diet and managed with regular vaccination and deworming practices. CR reported higher in the cows inseminated in spring (66.0%) than summer (45.0%), rainy (51.0%) and winter (59.0%) seasons	592
2015	To compare the CR between indigenous and crossbred cows after AI	The overall average 62.86% CR with highest CR in native (69.23%) than SL × L (67.92%) and HF × L (57.22%). Highest CR in age between 4 to 5 years (72.31-70.51%) than aged ≥ 9 years (43.48%), parity 3 (79.63%) and 4 (75.00%) than ≥ 5 <sup>th</sup> (73.91-41.67) parity.	569
2016	To determine the factors affecting CR in cattle	The CR of different genotypes varied from 59.13 to 63.65% with highest during summer and winter than rainy seasons. CR associated with semen quality and preservation, time of AI, breeds and seasons	573
2016	To detect the factors affect the PR in inseminated cows	The overall pregnancy rate (PR) has been reported to be 59.29% with highest PR at 4 years of age (70.27%), local cattle (69.07%) than RCC (60.0%) and and crossbred (48.75%) and 3 <sup>rd</sup> parity (67.74%)	574
2017	To synchronize estrus and AI with its success rate in cattle	Injection of GnRH (Fertilon <sup>®</sup> , Synthetic gonadorelin 100µg/ml, Techno Drugs, @ 5 ml/ cow) at the first day and injection PGF2α (Dinoprost <sup>®</sup> , Trometamol 5mg/ml Techno Drugs @ 5 ml/cattle) at 8 <sup>th</sup> day then again injection GnRH at day 10 was injected. Overall CR was 54.54% and service per conception rate was 1.38	593
2017	To investigate the influence of GnRH administration on CR at the time of AI in healthy crossbred dairy cows	The overall higher CR of 71.11% has been reported in GnRH (200-300µg at the time of AI) treated than control cows (55.56%) CR without GnRH treatment in cows. Significant effect of age and milk yield but no effect of doses, timing, BCS and parity in CR within GnRH treated cows	594
2018	To investigate the semen quality of Gov & private sectors and to improve the CR of dairy cows	Higher motility conc of semen in BRAC (30.16 ± 18.98) and lower in ACI (8.72 ± 0.77), whereas motility of spermatozoa also higher in BRAC (49.40 ± 9.76) and lower in Milk-vita (19.96 ± 3.16). Higher abnormalities in Pran Co. (22.86 ± 3.22) and lowest in ACI RAD (13.24 ± 1.80). The higher CR reported with PRAN (65.68%) and lower in Milk vita (39.01%) semen	595
2019	To determine the extent of influence various risk factors affecting the CR following AI in dairy cattle in the Sirajonj district	The overall CR 72.0% with higher CR in crossbred (HF × L 70.02%) than local 73.98%), removal of placenta > 6 hours (64.28%) than 0.5 to 1 hour (80.66%), age of cows < 2.5 years (50.0%) than 4.6 to 6 years (85.89%), 0 parity (58.89%) 0 parity (58.25%) to ≥ 5 (64.81%) than parity 3 (81.14%). AI after onset of estrus < 3 hours and calving interval > 551 days have been reported to be associated as risk factors of low CR in dairy cows	596
2019	To assess the performance of frozen semen of Brahman bulls with CR & influence factors	The overall average 55.3% CR with Brahman bull semen has been reported with highest CR in HC × L crossbred (68.9%), followed by SL × L (66.7%) and lowest in local (46.0%) cows. The CR has been reported to be influenced by breeds, milk yield and interval between estrus to AI in cows	597
2019	To comparison the CR in cows inseminated with DLS and BRAC semen	The CR of AI has been reported to be higher with BRAC semen (80.0%) than DLS semen (60.0%) and also the higher calving percentage with BRAC (75.0%) than DLS (55.05) semen	598

### Effects of the stages of estrus and semen on CR

The effects of the different stages of estrus cycle (Table 17) and semen (Table 18) on the conception rates in cattle is reviewed.

SN Breeding method	AI at different stages of estrus			SN Problems related to CR	Prevalence,%
	Early	Middle	Late estrus		
1. AI with 1 <sup>st</sup> day LS	61.54b (52)	69.01a (71)	34.88c (43)	1. Errors in estrus detection	29.94
2. AI with 2 <sup>nd</sup> day LS	60.87b (46)	66.67a (69)	30.95c (42)	2. Delayed insemination	35.03
3. AI with FS	57.61b (92)	72.20a (205)	35.71c (28)	3. Abnormal utero-vaginal secretion	09.98
				4. Cystic ovaries	02.94
				5. Miscellaneous causes	22.11
Estrus period <sup>596</sup>		Estrus period <sup>597</sup>		Estrus period <sup>586</sup>	
1. 09.1-12 hrs	CR 78.06	1. ≤ 12 hours	CR 38.1% (8/21)	1. 07-10 hours	CR 48.32%
2. 12.1-15 hrs	80.36	2. 13-18 hours	53.2 (42/79)	2. 11-14 hours	CR 60.26%
3. 15.1-18 hrs	76.61%	3. 19-24 hours	66.0 (33/50)	3. 15-18 hours	CR 39.42%

Insemination of cows and heifers at mid-cycle (12 to 15 hrs.) had significantly higher CR as compared to early and late cycles (Table 17). Concluded that estrus detection, correct timing of insemination, maintenance of proper cold chain of liquid and frozen semen, proper handling of semen with veterinary control would enable to achieve higher CR.

SN	Sources of semen	No. AI cows	Conception No. (%)	SN	Sources of semen	No. AI cows	Conception No. (%)
1.	DLS	1201	593 (49.62)	2.	Milk-vita	314	124 (39.01)
3.	ACI	392	150 (40.34)	4.	BRAC	600	378 (63.06)
5.	PRAN	405	266 (65.68)		<b>Overall</b>	<b>2912</b>	<b>1511 (51.88)</b>

### Embryo transfer (ET) in cows

The production of the first calf by embryo transfer in 1951 in Wisconsin following the surgical transfer of an abattoir-derived day-5 embryo,<sup>600,601</sup> since then the method has been progressively improved so that it can now be used for commercial ends.<sup>602</sup> There are two procedures presently available for production of embryos from donor females, (a) superovulation followed by AI and then flushing the uterus to gather embryos and (b) in vitro fertilization (IVF) consists of the recovery of eggs from the ovaries of the females then outside the body unit they are ready for implementation in foster females.<sup>603</sup> Although this technology is not commercially available in developing countries including Bangladesh, ET could provide opportunities for the conservation and the development of minor breeds.<sup>601</sup> The achievements of the AI are still not satisfactory in Bangladesh due to mainly unplanned AI practices as well as insufficient extension activities up to the farmer's levels. Moreover, only the AI practices cannot improve the genetic merits of

native cattle and multiple ovulation and embryo transfer (MOET) technology could be used for the development of cattle genotypes in Bangladesh. Recently some works on the MOET have been conducted in Bangladesh (Table 19).

Table 19. Research findings on bovine oocyte and embryo collection and production			
Year	Research objectives	Main findings	References
1982	A review on estrus synchronization	The role of estrus synchronization as a method of increasing animal production has been described	604
2000	To determine the effective dose of PMSG for the super-ovulation response in zebu cows	Regularly cycling dry native cows has been synchronized with IM injection 3.0 ml of Alfaprostol (Gabbrostim®) to each cow 48 hrs after the injection of PMSG for inducing estrus. Estrus cows have inseminated by AI with frozen semen 2-3 times at 12 hours apart. The uterine content then flushed with 150-200 ml medium and collected embryos have evaluated and graded. Results showed that the super-ovulatory response depends on the doses of PMSG and 1500 and 2000 iu found appropriate for cows.	605
2003	To collect bovine cumulus-oocyte-complexes from slaughter house ovaries	Follicles have been collected from three categories of ovary. Type I: having functional corpus luteum (CL), Type II: CL is in almost regressed condition and Type III: without CL. Significantly higher number of follicles of 2-6 mm diameter has found in Type III ovaries.	606
2012	To detect the ovarian response to different doses of FSH in three genotypes of cattle	The excellent quality embryos showed significantly highest yield (1.80) in the 240 and 280 mg FSH in local genotype. The highest yield (2.0) recorded with 320 mg FSH in Pabna variety, and 2.20 yield recorded in HF × L genotype with 180 mg FST.	607
2016	To adopt <i>in vitro</i> production (IVP) of bovine embryo using abattoir ovary	Results showed that 74.16% of the total immature cumulus-oocyte-complexes (COCs) have matured as detected by the presence of first polar body. It appears that the culture system support development of bovine embryo <i>in vitro</i> .	608
2016	To evaluate ovary, follicles and COCs and to compare collection techniques	Ovaries without CL and blunt dissection technique have been reported to be cumulus more suitable for harvesting the higher number and superior quality of cumulus -oocyte-complexes from slaughter cows	609
2017	To compare the maturation rate of immature oocytes after verification and warming between cryo devices	The <i>in vitro</i> maturation rate of COCs has been reported significantly higher in oocytes vitrified and warmed using crytop (47.1%) than that of French mini straw (15.9%). Significantly higher rate of <i>in vitro</i> maturation has also been reported in control (84.5%) than that of vitrified oocytes.	610
2018	To determine an effective basic medium and its hormone and protein of supplementation for IVM of oocytes of cows	It appears that both TCM (tissue culture medium) and MSOF (modified (modified synthetic oviduct fluid) may be used as a hormone supplement in basic medium for optimum IVM (in vitro maturation) rate of indigenous cows' oocytes.	611

## Dairy industry in Bangladesh

The first dairy plant was set up in 1946 by the National Nutrients Company at Lahirmonhanpur (Sirajgonj) in the then Indian subcontinent. After partition in 1947, the Eastern Milk Products Company took over through an exchange of properties. Milk and dairy products marketing eventually started in 1952 under the brand name Milk vita in the then East Pakistan.<sup>612</sup> Since 1973, cooperatives of smallholder dairy farmers have reorganized first as a dairy development program, the cooperative Dairy Complex with financial assistance from Denmark and later as the

Bangladesh Milk Producers' Co-operative Union Ltd. (BMPCUL; trade name as Milk-vita), formed in 1977. Currently, approximately 40,000 smallholder dairy farmers have become members of primary dairy cooperatives covering 925 villages in 15 districts including Sirajgonj, Tangail, Manikganj, Takerhat, Baghabarighat, Sree Nagar, Rangpur, Bhairab and Raipur, supplying over two million liters of milk daily. Of the total national consumption of 18 million tons per year of liquid milk, 15 million are produced domestically.<sup>613</sup>

Dairy farming is one of the ancient occupation established in smallholder farmers system in Bangladesh but its development is not at the satisfactory level mainly due to unplanned breeding, shortage of feeds and fodders, management, diseases and marketing of milk.<sup>582,614-618</sup> The dairy sector is an integral part of farming systems and has created both direct and indirect employment opportunity, improved food security and enhanced supply of quality protein to people's meals, contributing country economic growth and reducing poverty level in rural and urban areas of Bangladesh. Cattle, buffalo and goats are considered dairy animals in Bangladesh. Out of total milk production, about 90% is coming from cattle, 8% from goat and the remaining 2% from buffaloes.<sup>619</sup> There are about 6 million dairy cattle of which about 85 to 90% are indigenous and 10 to 15% are crossbred,<sup>503</sup> whereas 3.53 million are milking cows and 2.61 million are dry cows in Bangladesh.<sup>620</sup> However, the milk production depends on the genotype, proper feeding, management, breeding, housing and preventive measures against diseases and parasites.

### **Dairy production system in Bangladesh**

Dairy farms having more than 200 lactating cows and land for fodder cultivation are categorized as large dairy farms. Most of the large dairy farms in Bangladesh are two types managed which include Government owned and private sector dairy farms. These dairy farms have mostly crossbred cattle and some extent to some pure breeds cattle. Smallholder dairy farms distributed all over the country. However, the private dairy farms based on location can be categorized into three types, (a) Rural dairies (smallholder farms), (b) Pocket dairies (milk producing areas like Baghabarighat, Munshiganj, Takerhat) and (c) Metro dairies (developed at urban areas). There are four major dairy production systems in Bangladesh based on farm input and output levels. (a) Traditional, (b) Extensive, (c) Intensive and (d) Bathan systems.<sup>621</sup>

(a) The **traditional** system is characterized by small family farms (stallholder farms) in an integrated animal-crop production system with herd size vary from one to six cattle. Traditional smallholder farmers fed their cattle mainly on crop-by-product and residues, natural grasses and graze on communal land and also use shrub and tree leaves without any concentrate.

(b)The **extensive** system is practiced mainly by market-oriented dairy farmers operating on a small, medium and large scale farms. Animals are grazed for part of the day and are stall-fed during the rest. In addition to rice straw and green grasses, also provide some concentrate.

(c)The **intensive** system is characterized by zero grazing, with 2-10 cows, and the application of stall feeding systems using concentrate, rice straw and green fodder.

(d)The **bathan** system is characterized by a group of animals is reared near the banks of river, especially when monsoon disappears and water drains from the arable land, different leguminous fodders like matikalai, khesari kalai and also Jumbo, Napier and German grasses are cultivated and farmers allowed to graze these land during December to May every year.<sup>621</sup> Approximately 68% of the animals in Pabna and Sirajgonj districts are reared under the bathan system and 32% in the non-bathan system.<sup>622</sup>

### Research on smallholder rural dairy farms

Due to lack of pasture land and heavy demand of animal sources of protein especially milk, more than 70 to 80% of the cattle population is reared by individual farmers in the rural village management system with low productivity.<sup>621,623</sup> Smallholder producers dominate in the dairy sector and more than 70% of the dairy farmers are smallholders and produce 70-80% of the country's total milk.<sup>621</sup> Smallholder dairy farms in rural Bangladesh usually consist of 2 to 45 native lactating cows<sup>624,625</sup> with an average milk yield of 1.70 liter per cow per day.<sup>624</sup> Milk demand measured by per capita consumption is increasing by 4.0% per year which is higher than the growth in milk production (3.6%) and this has led to a continuous widening of the gap between milk supply and demand.<sup>621</sup> Smallholder dairy farms support the family income, nutrition, women employment and develop a village micro-economy in order to improve rural livelihoods and to alleviate rural poverty.<sup>259,626,627,628</sup> The Bangladesh Government launched a national program to increase milk production in 1991 by providing subsidies to dairy farmers who were rearing a minimum of five lactating dairy cows, either deshi, crossbred or exotic. This program was quite successful and the milk production greatly increased.<sup>613</sup> Currently, high milk yielding different crossbred cows are reared under smallholder farming system. Many scientists have performed their research on cattle production and health and also some important review articles have been published of the work of the different scientists.

### Breeds and population of dairy cows

Indigenous cattle consisted of (a) Non-descriptive deshi, (b) RCC, (c) Pabna cattle, (d) North Bengal gray, and (e) Munshigonj white cattle. Cross-bred cattle are the results of crossing between local with different exotic breeds like Holstein, Friesian, Sindhi, Sahiwal, Jersey at different level.<sup>503,629</sup> Approximately 85% cattle in Bangladesh are indigenous in origin.<sup>13</sup> Inclusion of quality genes over the past decades of crossbreeding resulted in crossbred cows of about 47% with an average lactation yield of 1838 liter in 266 days, while the similar performance of a local cow is 619 liter in 230 days, respectively. The crossbred cattle population has also increased milk production horizontally at the expense of genetic dilution.<sup>630</sup>

Smallholder dairy farmers are rearing different cross-bred at rural levels and most commonly 25.0% farmers rearing HF cross, 20.0% Sahiwal cross, 22.0% Sindhi cross and 33.0% indigenous cows in Bogura district in Bangladesh.<sup>631</sup> Farm owners had 85.4% crossbred (Friesian and Jersey) and 14.6% indigenous cows in Rangpur district.<sup>582</sup> Some research findings on breeds and population of cattle have been reported (Table 20)

- The small farmers by keeping 8 to 10 crossbred cows could earn a modest living by adopting small dairy farming as a profession<sup>582</sup>
- Holstein-Friesian crossbred cows were ranked best as dairy cattle.<sup>259</sup>

A total of 50 smallholder dairy farms have been investigated to study the management system of the farms and an average of 5.12 lactating cross-bred cows with an average milk production 5.78 liter / cow / day have been reported from Jossore.<sup>632</sup>

- The results showed that 98% of the dairy cattle are cross-bred (Pabna x HF, SL x Jersey) in Milk-vita area of Sirajgonj and Pabna with highest cross-bred population in the Shahjadpur, which is located close to the Milk-vita center and accordingly used of concentrate and AI better than other areas.<sup>622</sup>

Year	Major objectives	Major findings	References
1999	To evaluate the different breeds of dairy cows	Sahiwal cross-bred has been reported to be more suitable in BAUDF in terms of total milk yield and fat percentage.	633
2003	Smallholder dairy production system & its impact in the livelihood of farmers	HF cross, Sahiwal cross, Sindhi cross and indigenous cows have been used as the major breeds of lactating cows in the district of Bogura. Problems faced by the smallholder dairy farmers have been reported.	631
2005	To investigate the types of dairy breeds, productive & reproductive performances	Dairy farm owners had 85.4% cross-bred (HF & Jersey) and 14.6% indigenous cows, and 87% farmers used AI services. The productive and reproductive performances of dairy cows have been investigated.	582
2010	To determine the distribution pattern of crossbred dairy cattle and management practices in Milk-vita areas	The results showed that the 98% of dairy cattle in Milk-vita areas of Sirajgonj and Pabna are cross-bred (Pabna × HF, SL × Jersey) with highest population in the Shahjadpur. Shahjadpur is located close to the Milk-vita center and accordingly used more AI services.	622
2011	To assess the status of milk production and strategies for dairy development	The per capita consumption of milk demand is increasing by 4% per year which is higher than the growth in milk production (3.6%). Institutional support and sound policies are required for development	621
2012	To investigate the adaptability of different crossbred dairy cows under commercial farming condition in CTG	Dairy farmers in CTG areas reared cows with Holstein (HF x L) genetics in higher proportion (n=122) in comparison to SL x HF (n=50), SL x L (n=24) and J x L (n=11). Breed, farm condition, overcrowding, environmental stress, season of birth, feeding, management condition, diseases and replacement heifers are the main factors affects adaptability and survivability.	634
2012	Economic and genetic evaluations of RCC, L and H × L crossbred cows under rural level	RCC generated intermediate profit than HF × L crossbred and local cows for a one year operation. When life time productivity and calving interval has considered, RCC is supposed to generate higher profitability than the HF × L and local cows	635
2012	To estimate the genetic progress of RCC, local and crossbred cows and karyotype of RCC	Results showed that HF × L crossbred genotype have superior for all traits than RCC and local cattle. The RCC gives birth regularly that is one calf in a year and accordingly, the lifetime performance of RCC would be better than local and crossbred cattle.	636
2014	To investigate the scenario of dairy industry and the role of private sectors for its development in BD	There are 6 million dairy cattle in BD, of which about 85-90% are native and only 10-15% are crossbred. Native cattle consisted of (a) non-descriptive deshi, (b) RCC, (c) Pabna variety, (d) North Bengal gray and (e) Munshigonj white cattle. Crossbred consisted of crossing between local and exotic breeds like HF, Sindhi, SL and Jersey at different levels.	503

## Management of smallholder dairy farms

Smallholder dairy farming is the main source of milk supply in Bangladesh with a herd size 3.5 cattle per household being managed in traditional ways. Small and marginal dairy farmers rear lactating cows in the homestead for economic generating purposes.<sup>637</sup> General managerial information, feeding, breeding, housing and milking, productive and reproductive performances of the small scale dairy farms have been reported (Table 21).

## Cattle production, management and dairy products

Table 21. System of management of rural smallholder dairy farms in Bangladesh

Year	Objectives	Major findings	References
1998	To detect the problems of dairy farms	Problems associated with establishing of dairy farms in private sector have been reported	638
1999	To know the extent of involvement of family members in management of rural dairy farms	Approximate 60% house wives have been reported to be involved in rural dairy animals with highest participation in feeding (49.75%) and management (48.75%). Women have also involved in milking (27.0%), manure disposal (60%), milk selling (20.0%) and watering (82.0%) activities.	627
2001	To detect the management system of rural dairy cattle	Feeding of rural dairy cattle have been reported to supply 96% rice straw, 90% rice gruel and 83% green grass. The breeding of estrus cows are performed both AI (35.0% and natural services (22.0%).	639
2004	To investigate the management system of smallholder dairy cows at villages	Approximately 78% lactating cows milked once daily and 31.0 cows are bred by AI. Overall improved management practices have been suggested to improve the milk production.	640
2007	To study the management system of smallholder dairy farms	An average of 5.12 lactating cows producing 5.78 L/cow/d and 76% cows are inseminated by AI and 24% with both AI and natural services. Milking by 76% male, 20% female and 4% both	632
2007	To assess the status and prospectus of small dairy	The present status and prospectus of small scale dairy farming in the selected areas have been reported	641
2014	To assess the management of small scale dairy farms	Profitability of native has reported low in comparison with crossbred cows. Main problems in veterinary medical services and fodder	642

### Milk production and processing

Dairying is considered a major source of nutrition and income, and offers good opportunities for both farm families and non-farm rural and urban employment. Milk demand, measured by per capita consumption, is increasing by 4% per year, which is higher than the growth in milk production (3.6%).<sup>621</sup> The indigenous cows have been reported to produce 1.9 liter of milk per day against crossbred cows producing 7.8 liters/day.<sup>643</sup> The production and rural consumption of milk and milk products have decreased while import and urban consumption have increased. The urban consumption has increased due to increased urban population and faster increased urban income.<sup>644</sup> The municipality town households consume more milk, sweetmeats and dahi than rural and metropolitan city whereas metropolitan households consume more powder milk, condensed milk, ghee and ice cream.<sup>645</sup> Institutional support and policies play a major role in narrowing this gap and should therefore be considered in developing strategies for dairy development.<sup>646</sup> The research findings on milk production status in dairy cattle in Bangladesh have been reviewed (Table 22).

Table 22. Milk production status in dairy cattle in Bangladesh

Year	Objectives	Major findings	References
1994	To investigate feeding practices and milk yield based on farm size	The highest mean milk yield (liter/day) has been reported in large ( $2.43 \pm 0.87$ ), followed by medium ( $1.88 \pm 1.84$ ), landless ( $1.10 \pm 0.44$ ) and small ( $0.88 \pm 0.13$ ) native cattle dairv farms.	647

1994	To detect the efficiency of cow milk production	The cow milk production efficiency in a selected area of Bangladesh has been reported	648
1994	Milk yield of local and cross-bred cows	Comparative performance between local and crossbred cows has been reported in Bangladesh	649
1995	To investigate the milk production of crossbred and native cows	The crossbred and native dairy cows are reared as 0.16 and 0.87 per household in selected areas and produced maximum of 7.57 liter and 2.13 liter milk daily per cows, respectively.	650
1995	To evaluate the profitability of dairy raising	The analysis of dairy farm level data to detect the profitability of dairy farming in Bangladesh has been reported	651
1995	To compare the milk yield of different breeds of dairy cows in Sylhet	First lactation average daily milk yield has been reported highest in (L × F) × SL cows (5.56 kg) while for second lactation highest has been recorded in L × HF cows (5.15kg)	652
1996	To compare the milk yield of different genotypes of cows at CCBSDF	The pure breeds Local (n = 274), Sahiwal (n = 308) and HF (n = 77) have produced 653, 1056 and 2661 kg lactation milk, respectively F1 HF x L produced highest lactation milk (1956L).	653
2000	To find out the relationship between skin thickness and milk yield	Average milk production of low, medium and high skin thickness of hind-quarter cows have been reported to be 3.55, 3.27 and 2.79 liter per day in cross-bred (L × SL) lactating cows, respectively. Skin thickness may be associated with 29% variation of milk yield.	654
2001	To identify the development and production pattern of milk in BMSA	The milk collection, number of society members and the productivity of the lactating cows have increased due to extension activities and breeding policies of Milk-vita but the economic status of the dairy farmers remain unchanged.	655
2001	To compare the milk yield between native and crossbred cows in mini dairy farms	The average ranged of milk production in native cows varied from 0.52 to 3.62 liter/cow/day whereas in crossbred it varied from 1.78 to 10.15 liter /cow/day. The average lactation period of native cows (221.25 days) has been reported to be lower than crossbred (281.7 days). Rearing of crossbred cows is more economical than native cows.	656
2001	To detect the effect of udder shape and size on milk production in crossbred cows	Three types of udder shape with their milk production including bowl (16.0%; 3.6kg), round (55.0%; 2.7kg) and goaty (9.0%; 3.2kg) have been reported in crossbred lactating cows. A bowl shaped udder with large proportion of secretary tissue with highest milk yield has been reported as an asset for a milch cows.	657
2001	To assess the genetic lactation of cows	The genetics of lactation of Pabna and its crosses with Sahiwal and Friesian cows have been reported	658
2002	To detect the differences of milk yield between native & crossbred cows	Milk production (L/cow/d) of native cows has been reported significantly higher in Munshiganj (5.72) and Sirajgonj (5.66) than Tangail (2.94), Rangpur (2.24) and Madaripur (2.11) mainly due the availability of fodder whereas crossbred cows produced 7.86 L/cow/day.	659
2002	To identify the quality milk production trend of Milk-vita throughout the year	Results showed that the highest milk production recorded in February (10.01%) and lowest in September (6.46%). The year round monthly milk production of Milk-vita recorded as 9.97, 10.01, 9.20, 8.59, 8.17, 8.37, 7.27, 6.50, 6.46, 6.86, 8.73 and 9.88%, respectively	660
2003	To detect the effects of milk vein and parity on milk yield in dairy cows	Higher milk yield has been recorded at 3 <sup>rd</sup> lactation and thereafter decreased. Linear length (33.0 cm), tortuous length (3.5 cm) and thickness (1.43cm) of milk vein had maximum size at 3 <sup>rd</sup> lactation. A well develop milk vein indicates better milk producing ability.	661

## Cattle production, management and dairy products

2004	Performances of native & cross-bred cows	Comparative performances of crossbred and indigenous dairy cows under smallholders management have been reported	662
2005	Performances of native & cross-bred cows	Comparative performances of crossbred and indigenous dairy cows under small orders management have been reported	663
2005	Performances between Local & crossbred cows	Performances of different crossbred and local dairy cows at Takerhat milk shed area have been reported.	664
2005	To detect the productive reproductive status of dairy cows	Daily milk yield / cow/ farm has been recorded as 4.27 liter for cross-bred and 1.78 liter for native cows. Smallholder dairy farmers could earn a modest living by rearing 8-10 dairy cows.	582
2005	Teat and udder shape and milk yield in cows	The udder shape and teat measurements and their relation with milk production in indigenous dairy cows have been reported	665
2005	Economic benefit of rearing native and crossbred cows	Economic benefits of rearing indigenous and crossbred dairy cows under smallholder dairy farming system in Bangladesh have been reported	666
2006	To assess the effects of management on fertility and milk production	Management improvements directed towards increased average milk production cow/day. The age of first calving 35-44.3 months, calving interval 14-17.6 months, lactation length 249-286 days and 3.5-7.2 liters milk yield have been reported.	667
2007	To detect the effects of feed and breed on milk production in dairy cows	HF crossbred cows has been reported as ranked best dairy breed of cattle. Feeding of fodder has increased milk production and decrease disease prevalence.	259
2007	To detect the influence of month on milk production in dairy cows.	The highest milk production has been recorded in February (10.01%) and lowest in September (6.46%) and then gradually increased up to February that indicate a specific trend of milk production in the year.	668
2007	To detect the milk production trend	The milk production trend of Takerhat milk shed area of Milk-vita around the year has been reported	669
2008	Performances of local & crossbred cows	Productive and reproductive potentials of native and crossbred dairy cows under farm condition have been reported.	670
2008	To detect the daily and lactation milk yield in RC lactating cows	Analysis of five lactation milk yield of 41 RC lactating cows showed an average daily milk yield as 1.99 liter and 453.86 liter/ lactation. The milk yield of RCC and other native cows is below the expectation.	671
2009	Effects of seasons & feed on milk yield in native & cross-bred dairy cows	Native cows yielded an average of 1.5 liter milk /cow/day against 5-8 liter in crossbred cows. The low milk production in dairy cows in Bangladesh has been suggested due to mainly to genetic and nutritional constraints.	30
2009	Relationship between genotypes & milk yield	The predicted highest lactation milk yield (1813.62 kg) has been reported for cow which carried 75% of HF blood (e.g. 75% HF × 25% local)	672
2011	To compare the milk yield between native and crossbred cows	The overall milk production of native cows has been reported to be 1.672 liter/day and crossbred yield 9.55 liter/ day and accordingly, the crossbred cows have reported to be superior to local cows.	673
2011	Influence of genotypes on milk production	The milk production of different genotypes of dairy cows have been reported.	674

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2011	To estimate the BLUP breeding values of milk yield traits of cows	The best linear unbiased prediction (BLUP) breeding values of production traits for HF and its crosses have been estimated. The HF × Local scored higher when compared to other genotypes.	675
2012	To evaluate milk yield and composition based on region, season, genotypes & lactation in cows	Milk yield and composition have been reported to be associated with feed base region, genotype and lactation of cows. Milk yield negatively correlated with the percentage of fat, protein, lactose, SNF and milk composition.	676
2012	Cross-bred status in rural semi-urban areas	Only 35% farmers adopted crossbred of which 17.5% in rural and 70% semi-urban regions	677
2014	To identify a suitable milk-recording protocol for small-scale dairy production	The higher average daily and lactational milk yield has been reported in HF × L than SL × L crossbred cows. The test day milk yield of 1 and 2 weeks interval has found to be fitted with the actual 210-days milk yield by using Wood model for both crossbreds.	678
2014	To compare the lactation milk yield between cross-bred and deshi cows	An average lactation milk yield of 1838 liter in 266 days has been reported in crossbred cows while it has been documented as 619 liter in 230 days in indigenous dairy cow.	630
2014	Milk yield between native and crossbred cows	The average daily milk yield has been reported to be 8.71 liter in crossbred cows whereas only 1.78 liter in indigenous cows	642
2014	To quantify the influence of dietary energy and protein intake on yield & composition of milk	The average ME (94.59 MJ/d) and CP (1675.80 g/d) significantly influenced milk yield, milk fat, protein, lactose, TS and ash content of milk in cross-bred (HF × SL) cows. Adequate dietary ME and CP are required for optimum yield and composition of milk of crossbred cows	679
2015	To quantify the influence of BCS on yield and composition of milk	BCS significantly has reported to be affected milk yield, milk fat & ash content in crossbred (HF × SL) cows. Highest milk yield (13.45l/d) recorded with moderate BCS (3.0) compared to lower (2.75-2.25) & higher (3.25-4.0) BCS	680
2015	To detect relationship between milk yield & ovarian cyclicity (OC) in dairy cows	The highest milk yield reported in HF x L cross cows (5.4 L/d) in comparison to SL x L (3.6 L/d) and local (2.0 L/d) cows. The HF x L cross cows has started ovarian cyclicity earlier (80.2 days) with higher rate (37.9%) than local (84.8 days) with 13.3%	681
2016	To compare the morning and evening milk of dairy cows	The evening milk has been reported to be better than morning milk. Morning milk showed less yellowish than evening milk, higher specific gravity in morning (1.030) than evening milk, and higher TVC and coliform count in morning than evening milk.	682
2016	To detect the seasonal effect on milk production and qualities of crossbred dairy cows	The highest milk production has been reported during rainy season (3354.0kg) followed by summer (3116.7kg) and lowest during winter (2925.5 kg). Season had a significant effect on the milk quality and quantity except for protein, lactose, SNF & coliform	683
2017	To compare the milk production of crossbred cows maintained in household & bathan levels in Milk-vita regions	The genetic admixture with the combination of several breeds in which the frequency of HF has been reported to be highest predominant breed characteristics, followed by Jersey and Sahiwal with local mainly Pabna cattle. No difference on the peak milk yield (PMY) in both the household (18.95) and bathan (18.57) in HF x L but higher in PMY reported higher in household (19.33) than bathan (15.57) by the Jersey cross cows.	684

## Cattle production, management and dairy products

2017	To detect the age and lactation-wise milk yield in 100 HF x L crossbred cows	The highest milk yield (13.11 L/cow/day) and longest lactation period (247.14 days) have been reported in cows aged between > 72 to 150 months of age. Approximately 87.0% cows have produced peak milk at the second month of lactation period.	581
2018	To estimate the genetic parameters of milk yield traits and performance of RCC	The average lactation length (LL), lactation milk yield (LMY) and daily milk yield (DMY) have been reported to be 205.65 days, 455.53 kg and 2.20 kg in <i>in-situ</i> and 204.79 days, 702.35kg and 3.40 kg in <i>ex-situ</i> , respectively in RCC.	51
2018	Factors & profitability of dairy farming	Despite problems and constraints in dairy farming and milk yield, it is still profitable in the CTG	685
2018	To evaluate the effect of lifetime milk production performance of different crossbred cows	The productive performances of HF x L genetic group has been reported superior compared to other crossbreds. However, the LH x F (Local x Haryana x Friesian) ranked the highest in terms of total lifetime productivity in comparison to other crossbred.	686
2018	To determine the effect of UMN and DCP on silage quality and milk yield of cows	The 23.70, 23.19 and 27.06% milk production increased those crossbred (HF × L) cows received Napier, UMN (urea-molasses napier) and DCPN (di-calcium phosphate napier) silage, respectively. The addition of DCP as additive during silage making would be beneficial for the dairy cows	687

Dairy cattle production in Bangladesh is characterized by low productivity levels mainly due to genetic and nutritional constraints. Local cows yield on average 1.5 liter milk per day against 5 to 8 liter in cross-bred cows in Bangladesh.<sup>30</sup> The cost of rearing cross-bred cows reported higher than indigenous cows but it is compensated by higher milk yield, hence rearing of cross-bred cow is advisable in study area Sirajgonj district.<sup>651</sup> A local cow is produced an average of  $256 \pm 2.64$  liters of milk per lactation that increase in overall family income at the rural level in Bangladesh.<sup>688</sup>

Milk production (L/d) of local cows has been reported to be significantly higher in Munshiganj (5.72 liter) and Sirajgonj (5.66 liter) followed by Tangail (2.94 liter), Rangpur (2.24 liter) and Madaripur (2.11 liter), these difference of milk production of local cows has been explained mainly due to the availability of fodder and genetic status. The average daily milk production and average lactation period of cross-bred cows have been repowered as 7.86 liter and 269 days, respectively.<sup>659</sup> Daily milk yield /cow / farm has been reported to be 4.27 and 1.78 liters for crossbred and local cows respectively in Rangpur.<sup>582</sup>

- The per day milk production has also been reported to be 1.86 liter in local cow whereas 5.94 liter in cross-bred cows and the income level from milk yields of crossbred cows reported as 3.19 times higher than the local cows.<sup>689</sup>
- The highest milk production has been reported during the month of February (10.01%) and lowest during September (6.46%) of Milk-vita societies in Bangladesh.<sup>668</sup>
- An average lactation yield of 1838 liter in 266 days in crossbred cows, while the similar performance of a local cow 619 liter in 230 days has been reported.<sup>630</sup>
- Approximately 78% smallholder dairy farmers are milked their cows once daily and about 31.0% are used AI for breeding their cows.<sup>640</sup>
- Milking is usually done by male 76%, female 20% and both 4% milkers in Jossore.<sup>632</sup>

### Market share of milk by the different companies

Currently, around 10% of the total milk production goes to brands produce pasteurized milk and dairy products whereas 90% milk sale in the local market immediately. A total of 14 companies have registered under Bangladesh Standards and Testing Institution (BSTI) and they produce and supply pasteurized milk and dairy products in the markets (Table 23).<sup>690</sup>

Table 23. Market share of liquid milk among different companies <sup>503,691,692</sup>					
SN Processing Co.	Established Year	Av. Milk collection (liter/day)	Market share (%)	No. of small-holder farmers	BSTI tested milk samples (dhakatribune.com) <sup>690</sup> (Established year)
01. BMPCUL (Milk-Vita)	1973	200,000	52.08	150,000	01. Aarong Dairy (1998)
02. BRAC Dairy (Aarong)	1998	80,000	20.83	70,000	02. Farm Fresh milk (2007)
03. Pran Dairy Ltd.	2001	40,000	10.42	30,000	03. American Dairy (2010)
04. Amo milk	1996	10,000	02.60	05,000	04. Milk-vita (1973)
05. Bikrompur Dairy	1998	10,000	02.60	06,000	05. Aftab (1998)
06. Ultra Shelaide Dairy	1998	10,000	02.60	04,000	06. Ultra
07. Aftab Dairy	1998	08,000	02.08	04,000	07. Tania
08. Tulip Dairy	1998	03,000	00.78	02,000	08. Igloo (2004)
09. Grameen /CLDDP	1999	07,000	01.32	06,000	09. Pran milk (2001)
10. Grameen-Danone	2007	01,000	00.03	-	19. Dairy Fresh (2012)
11. Rangpur Dairy	2007	08,000	02.08	07,000	11. Milk Fresh
12. Farm Fresh	2007	04,000	01.04	00,500	12. Cowhead Pure milk
13. Savar Dairy	1974	06,000	01.54	Govt. farm	13. PURA
<b>Total milk collection/day</b>		<b>387,000</b>	<b>100</b>	<b>284,500</b>	14. Ayran

It appears that the efficiency of dairy industry especially milk processing activities increased and industry became more progressive because of the advancement of new technology.<sup>692</sup> Table 23 shows that only three companies including Milk vita (52.08%), Aarong (20.83%) and Pran Dairy Ltd. (10.42%) have highest market share in comparison to other companies. Dairy industry in Bangladesh is faced by several constraints that include poor genotype, limited food availability, inadequate health care service, lack of cold chain, poor transportation, and unorganized marketing system.

### Milk-vita

The first dairy plant with a capacity of 2000 liters per day was established at Lahirimohanpur (Sirajgonj) in 1946 with the target to sale milk products in Calcutta market that was within the easy rail communication system. After the partition, Eastern Milk Products Limited, a private company purchased this dairy plant in 1952. In 1965, the first milk producer's co-operative was formed under the name Eastern Milk Producers' Co-operative Union Limited (EMPCUL). The nomenclature of the organization was changed to 'Bangladesh Milk Producers' Cooperative Union Limited' immediately after liberation by the Bangladesh Government in 1973 with keeping its brand name 'Milk-vita.' It possesses 52.08-63% market share of liquid milk, which provides various services to dairy farmers like milk collection facilities, veterinary medical services, AI services, balanced cattle feed, loan for cattle purchase and others services related to dairy farmers for increasing milk production and milking cow improvement.<sup>693</sup> Currently, Milk-

vita is the largest pioneering dairy cooperative venture in Bangladesh deals with about 350,000 liter / day liquid milk production, collection, processing and marketing with a diversified set of dairy products.<sup>694</sup> Milk production increases 5.98% per year where demand increases by about 10% due to an increase in purchasing capacity and food habit change of consumers in Bangladesh.<sup>694</sup>

### BRAC Dairy

BRAC Dairy was established in 1998. It began as an income-generation sector to create a market for rural dairy farmers and provide them a profit-making platform. Currently, BRAC Dairy collects cows' milk from rural dairy farms to the 101 chilling centers and sells them in nationwide through its internal and external distributors and retail chains under the brand name Aarong Dairy. It has the processing capacity of 170,000 liters of milk per day and holds 20.83-24.00% of the national market share. Currently, this enterprise serves approximately 50,000 dairy farmers in the western region of Bangladesh including Khulna, Dhaka, Rajshahi and Rangpur) with over 1400 employees working under this umbrella.<sup>695</sup>

### Pran Dairy (Pran Dairy Ltd.)

The Pran Dairy has established in 2001 as Pran Dairy, a sister concern of Pran Group which is the 3<sup>rd</sup> largest dairy milk processor in Bangladesh has the capacity to collect 200,000 liters of milk daily from the existing five dairy hubs. The company has setup 101 milk collection and chilling centers, around 20 centers per hub to collect milk from nearly 12,000 contract farmers having over 50,000 cows.<sup>696,697</sup>

### Economics of dairy farming

The rank of the major cost items related to importance of milk production includes the concentrate feeds, green grass and labor cost. The major problems of milk production in the bathan areas are the rain and thunder storm, scorching sunshine and low prices of milk. This study has suggested that if the cattle could be sheltered in sheds and support price of milk be ensured, milk production in the bathan areas would be profitable enterprise.<sup>698</sup>

A dairy farm with 13 to 15 months calving interval, 24 months for age at puberty, 1.33 services per conception and 5.0 kg milk per day per cow have been reported economically profitable.<sup>699</sup> Research findings on the economics of dairy farming are reviewed (Table 24).

Years	Objectives	Major findings	References
1993	Assess economics of milk production	The economics of milk production in selected areas of Bangladesh has been reported	700
1994	Assess major problems of milk production in bathan areas	Rain and thunder storm, scorching sunshine and low milk price are the major problems. Animal shelter in shed and support milk price have been suggested for profitable bathan enterprise.	698
1994	To compare the cost and return of rearing native & cross-bred cows	The benefit-cost ratio of milk/L has reported higher in cross-bred (1:1.33) than native (1: 1.04) cows. This study has recommended dairying with cross-bred cows for viable enterprise.	701

1095	To compare the cost of rearing cross and native cows	The cost of rearing cross-bred cows has been reported to be higher than native cows but it is compensated by higher milk yield. Hence rearing of cross-bred cow has been advised in this study.	651
1995	To evaluate the economics of dairy farming	Overall balance : cost ratio has been reported as 1 : 1.03 which indicates that mini dairy farming is economically profitable.	702
1996	To assess the economic differences of rearing dairy breeds and areas	Rearing of exotic and their crosses dairy cows have been reported to be more profitable compared to indigenous cows. Dairy farming has also found more profitable in Dhaka city area than Rangpur.	703
1997	To find out the sector involvement of farmers	About 68% farmers are involved in crop and only 6.5% in livestock rearing and have suggested to utilize this data for development plan.	94
1997	To assess the economic profit of mini dairy farming system	Most of the mini dairy farmers have earned annual income ranged from Tk. 25,001 to 50,000. Some problems associated with mini dairy farming system have been reported and described.	623
1998	To detect the milk yield & economic status of rural dairy farm families	An average milk production in cow of the rural dairy farm families has reported as $256 \pm 2.64$ liter / lactation. Providing loan to the dairy farm families has been suggested to enhance milk production.	688
1999	To assess the rearing of livestock species and management practices	About 91.7% farmers rear cattle, 82.8% chicken and 71.3% ducks. About 19% farmers did not use any vaccines, 27% used vaccines and 38% have concerned with Vet and 22.4% income from livestock.	704
1999	To analyze the profitability of ideal dairy farm project financed by Krishi bank	The profitable status has been reported of all the dairy farms funded by Krishi bank and it has reported that the total cost of dairy farming decreased with the increase of farm size	705
1999	To analyze the profitability of ideal dairy farm project financed by Krishi bank	The dairy farms funded by Krishi bank have been reported to be marginally profitable with benefit-cost ration of 1.13.	706
2000	To identify the some economic traits of five genetic cows	It has been concluded that L × SL F1 cows found better for milking traits and L × Haryana F1 cows for reproduction traits than other crossbred (L × Friesian, L × Sindhi & Local) cows.	707
2000	To compare the economic benefit of dairy farming between two areas	The owners have earned an average of BDT 29.42 and BDT 29.34/ cow with 2.33 and 2.38 man-hours in two areas, respectively. It has suggested to increase more inputs and full time for dairy farms.	708
2000	To evaluate the fertility status of smallholder dairy cows	Delayed age at first calving, low milk yield, high production cost, low milk to concentrate feed ratio and poor reproductive performances caused an average of BDT 39,493/- year in mini dairy farm.	709
2002	To assess the awareness of growing dairy farmers	Necessary awareness to utilize resources with efficiency which would enable to the growing farmers to obtain econo-micro-returns.	710
2003	To determine the non-survival of subsidized & non-subsidized dairy farms	Overall 30.88% non-survivability of dairy farms due to (a) non-profitability, (b) scarcity of feed & fodder, (c) lack of Vet cares, (d) milk marketing problem and mortality of cows and calves.	711
2003	To detect the influence of loan on the activities on the dairy farms & production	Loan to the dairy farm owners has a positive impact on dairy industry development as it caused to increase Number of lactating cows, milk production and gross income in dairy farms.	712

## Cattle production, management and dairy products

2004	To evaluate the economics of dairy farming at five milk pockets	Higher number of crossbred cows (4.58; 71%) are reared than local cows (1.87; 29.0%) with twice time higher milk yield in crossbred than local cows. Profit obtained ranged from 10,855 to 2,23,444 with an average of 75,950/- taka depend on farm size.	713
2004	To analyze the impact of government's subsidy on the development of private dairy farms	Age at first calving, calving interval and dry period have been reported to be significantly lower and lactation length significantly increased at post-subsidy than pre-subsidy dairy farms. Overall milk production, fodder production and labor employment significantly higher in subsidized than non-subsidized dairy farms.	714
2009	Economics of dairy farming operated through milk supplying process through BRAC's milk supply chain	The annual average gross return and gross margin per cow have been reported to be Tk. 105097 and Tk. 39019, respectively with net return Tk. 30582/- Major problems faced by the dairy farmers are capital, feed, fodder and pasture land, breed, AI and veterinary service	715
2009	To evaluate the economics of smallholder dairy farming in Satkhira	The annual average milk production and net return per farm have been reported higher in member (7215.87 liter & Tk. 175670.30) with field fertility clinic than non-member (5206.52 liter & Tk 67611.51) farms.	716
2010	To compare the profitability of dairy farming between member and non-member of field fertility clinic	Total cost of raising a dairy cow has been estimated at TK. 142.04 and Tk. 158.21 / day for member and non-member farmers to FFC, respectively. All the selected variables except paddy straw had significant impact on milk production.	717
2010	To assess the economics based on rearing systems and dairy farm sizes	Intensive dairy farming system with large size produced higher milk yield with lower cost than extensive and traditional farming systems with high costs of milk production.	718
2010	A comparative evaluation on cost benefit analysis between rearing of cross-bred and native cows	The per day milk production has been reported as 1.86 liter in local cow whereas 5.94 liter in cross-bred cow and the income level from milk yields of crossbred cow recorded as 3.19 times higher than the local cow.	689
2014	To compare the livelihood status of GOV and NGO supported with self-managed dairy farms	Productivity and profitability of GOV and NGO supported dairy farming have been reported to be higher than the self-managed dairy farms due to intervention. Net return has reported higher with GOV (Tk. 52601.8), followed by NGO (Tk.48819.1) and lowest with self-managed (Tk. 27194.5) dairy farms.	719
2016	To assess the 'one house and one farm' project	The household income, employment opportunities and capital of project farmers increased in compare to non-project farmers.	720
2016	To analyze the socio-economic factors that influence milk production in dairy cows	The socio-economic factors affecting milk production & OB WU (on-farm blue water use) have a highly linked with adaptation of efficient management tools to guide the dairy farmers to allocate water resources effectively for increasing milk production.	721
2016	To assess the farmers' input cost with respect to sustainable profit in dairy farming	Labor input cost has been reported as most important cost which effect sustainable profit compared to straw and other inputs. Higher sustainable profit in commercial than traditional farming.	722
2018	To explore the management and institutional factors associated with dairy farms profitability	Results showed that the dairy farm in is profitable business but it has been facing problems of farm operation and selling of milk. It would be required to overcome the problems of low income, unemployment and under nutrition of the country	685

2019	To assess the socio-economic farm and technological aspects of dairy farms	The price of milk varied from region to region with higher in urban market. Results showed that 62.7%, 52.9% and 51.0% dairy farm families have smartphone, facebook and internet users, respectively. Technological based milk market linkage could be created.	723
2019	Economic analysis of dairy farming	Smallholder farms have owned av. 3.07 lactating cows consisting of 0.37 native and 2.70 crossbred cows. Native cow produces 1.9 & crossbred 6.48 liter/d. Crossbred provided higher economic benefit than native cows.	724

### Economic analysis of dairy farms

Table 25 shows the annual production cost of mini dairy farms and Table 26 shows the overall livelihood status of GO and NGO supported dairy farmers' with self-managed farmers.

SN Item of expenditure		C. Annual returns of mini dairy farms	
<b>A. Variable cost (VC):</b>	Overall, %	SN Source	Overall, %
1. Concentrate	35.19	1. Sale of milk	69.43
2. Rice straw	11.46	2. Sale of ploughing	02.26
3. Green grasses	07.17	3. Sale of cow-dung	04.13
4. Labor charge	23.64	4. Sale of cattle	12.60
5. Veterinary charge	01.64	5. Calves & heifer	11.58
6. Fodder cultivation	00.50	Gross return	100
7. Transportation	02.68		
8. Miscellaneous*	01.45		
9. Interest on operating cost	03.28		
<b>Total variable cost</b>	<b>86.99</b>		
<b>B. Fixed cost:</b>			
1. Depression of cow-shed	00.66	•Crossbred (2.55) and native (0.65) cows	
2. Depression of cow	11.43	•Higher milk production in crossbred (5.66L/d) than native (2.23 L/d) cows	
3. Depression of equipment	00.35	•Higher lactation period in crossbred (304 days) than native (210 days) cows.	
4. Interest on fixed capital	00.57	•Benefit : Cost ratio = 1 : 1.03	
<b>Total fixed cost</b>	<b>13.01</b>		
<b>Total production cost (VC +FC)</b>	<b>100</b>		

•Overall benefit : cost ratio was 1 : 1.03 indicates that mini dairy farming is economically profitable in the rural areas of Bangladesh.

The profitability of 60 Ideal Milk Farm programs financed by Bangladesh Krishi Bank (BKB) in three selected districts (Mymensingh, Dhaka and Narayangonj) have been evaluated that the total cost of dairy decreased with the increase of farm size.<sup>705</sup> It appears from another study that the BKB loan funded dairy farms are marginally profitable with benefit cost ratio 1.13.<sup>706</sup> Labor and concentrates constitute the major share in the cost components of maintenance of cows. Productivity and profitability of supported dairy farming was higher than the self-managed due to intervention.<sup>719</sup>

The profitability reported greater with cross-bred than with local bred animals (Table 27).<sup>649,662-664,666,670,726,727</sup> So, dairying should be encouraged with cross-bred cows in Bangladesh.<sup>701</sup> Native

Cattle production, management and dairy products

Table 26. Overall livelihood status of Government (GO) and Non-government organization (NGO) supported dairy farmers' with self-managed farmers.<sup>719</sup>

SN Parameters	Farm management status			
	Self	NGO	GO	
<b>A. Cost items (%)</b>				
01. Labor cost	17.4	17.2	16.7	<b>Conclusions</b> <ul style="list-style-type: none"> <li>•The income of the dairy farms have been reported to be increased of Tk.25400.0 due to intervention.</li> <li>•The labor, paddy straw, green grass and concentrate feed cost have been reported to have significant effect on gross returns from milk production for both the supported and self-managed farmers.</li> <li>•There is a scope to improve the overall livelihood status of dairy farmers.</li> </ul>
02. Feed cost	53.4	55.4	55.1	
03. Veterinary cost	03.6	02.8	02.9	
04. Miscellaneous cost	01.7	01.6	01.7	
05. Interest on operating cost	04.6	04.6	04.6	
06. Total variable cost	80.7	81.7	80.9	
07. Housing	03.5	03.2	03.5	
08. Interest on capital invested	15.8	15.2	15.6	
09. Total fixed cost (TFC)	19.3	18.3	19.0	
10. <b>Total cost (TC)</b>	100	100	100	
<b>B. Return items (%)</b>				
1. Milk	20.7	40.5	40.6	
2. Net charge in inventory	77.8	58.3	58.2	
3. Others	01.5	01.2	01.2	
4. <b>Gross return (GR)</b>	100	100	100	
5. Net return (NR)= GR-TC)	27194.5	48819.1	52601.8	
6. BCR (undiscounted)(GR/TC)	1.8	2.3	2.4	
BCR = Benefit : Cost ratio				
Total cost and return of dairy farming (Tk/dairy cow/year) [%]				

Table 27. Comparison the cost and return of rearing between native and cross-bred cows<sup>727</sup>

SN Parameters	Native cows Total Tk (%)	Cross-breed Total Tk (%)	SN Parameters	Native cows Total Tk (%)	Cross-breed Total Tk (%)
<b>A. Cost items/day</b>					
01. Feed cost	19.01 (57.88)	44.42 (62.36)	08. Other feed cost	00.01 (00.02)	00.02 (00.02)
02. Paddy straw	13.96 (42.48)	18.67 (26.22)	09. Labor cost	11.37 (34.61)	20.17 (28.32)
03. Green grass	01.55 (04.72)	06.18 (08.68)	10. Housing cost	00.29 (00.88)	00.43 (00.60)
04. Oil cake	01.35 (04.12)	10.14 (14.23)	11. Vet. cost	00.21 (00.63)	01.28 (01.80)
05. Bran	01.79 (05.44)	06.26 (08.79)	12. Capital cost	01.74 (05.29)	04.60 (06.46)
06. Common salt	00.08 (00.24)	00.22 (00.31)	13. Misc. cost	00.24 (00.72)	00.33 (00.46)
07. Molasses	00.28 (00.85)	02.93 (04.12)	<b>Total cost</b>	<b>32.85 (100)</b>	<b>71.23 (100)</b>
<b>Return</b>					
01. Milk	51.24 (87.94)	210.00 (93.43)	04. Calf	04.41 (07.57)	11.77 (05.24)
02. Cow dung	02.22 (03.81)	02.89 (01.29)	05. Total return	58.27 (100)	224.76 (100)
03. Other uses	00.40 (00.69)	00.10 (00.04)	<b>06. Net return</b>	<b>25.42</b>	<b>153.53</b>

cows produced 0.63, 1.78 and 0.84 liters, whereas cross-bred cows produced 34.42, 10.00 and 4.75 liters per farm for large, medium and small farms, respectively.<sup>725</sup> However, the productive and reproductive performance of crossbred cows reported better than local cows.

To identify the development and production pattern of the smallholder dairy farmers of the

Milk-vita society shows that the collection of milk, number of active society and members, number and productivity of lactating cows improve year to year due to increase in extension activities and breeding policies of Milk-vita. But lactating cows per member (2.06) yet not increased indicates that the economic status of farmers remain unchanged.<sup>655</sup> Economic of dairy farming in Satkhira district has comparatively increased in terms of milk production and cash income in members of field fertility clinics (FFC) than non-member farms.<sup>716,717</sup>

The impact of the government subsidy on the development of private dairy farms has been evaluated on 200 pre-subsidized and 200 post-subsidized dairy farms in 6 divisions in Bangladesh. Overall milk production, fodder production and labor employment have significantly higher in subsidized than non-subsidized dairy farms in Bangladesh.<sup>714</sup> Most of the dairy farmers believe that dairy farming is a profitable enterprise and can be more profitable if Government gives support on feed cost, marketing, loan and dairy farm management training.

### **Research on reproductive and productive performance of dairy cattle**

The dairy cattle improvement program has been launched to improve native cattle for milk production by incorporation of both tropical (Sahiwal & Sindhi) and temperate (Holstein-Friesian & Jersey) breeds in Bangladesh. The productive and reproductive performances of different local, pure and crossbreds cattle have been partially reviewed in Bangladesh.<sup>728,729</sup> The reproductive performances of both the indigenous (90%) and crossbred (10%) cattle of Bangladesh have been reported to be poor, required average two services for conception, calving interval between 365 to 536 days and post-partum service period between 103 to 161 days.<sup>729</sup> Analysis of reports showed that the Holstein-Friesian crossbred cattle performed comparatively better than others crossbred.<sup>728</sup> Supplement of UMMB (@ 250g / head / day) has reported a positive effect on fertility of the local cows under village condition of Bangladesh.<sup>397</sup> Recently, the Field Fertility Clinic (FFC) services caused to increase the total milk production, total return and net return per head of cow which indicates the positive impact for dairy development.<sup>717</sup> The influence of season and month on first service conception rate<sup>730</sup> and age, parity and farming condition<sup>731</sup> in cattle have been reported. For accurate analysis of data, the definition of the productive and reproductive indices is required.<sup>732</sup>

- Birth weight- Live weight of calves recorded within 24 hours of birth.
- Growth rate- Weight gain per day
- Lactation length- Interval between first and last milking of a cow in the same lactation
- Lactation milk yield- Quantity of milk given by a cow over a lactation period
- Daily milk yield- Lactation milk yield divided by lactation length
- Age at puberty- Age at which heifer allowed for first service
- Weight at puberty- Weight at which heifer allowed for first service
- Age at first calving- Age at which heifer gave first calf.
- Service per conception- Average number of services required for each successful conception
- Post-partum anestrus period- Interval between date of a given calving and the date of first insemination after parturition
- Gestation length- Days between effective inseminations to concerned calving
- Calving interval-Days between two successive calving.

## Cattle production, management and dairy products

Reproductive performance of cattle (heifers and cows) is one of the most important factors that influence ranch profitability. Understanding the biological mechanisms associated with getting a cow or heifer bred can be a significant management tool for increasing realized income. The mean values of all the available published articles on productive and reproductive performances of different genotypes of cattle in Bangladesh have been reviewed and it appears that the mean values of these parameters varied greatly (Table 28a-d).

Table 28 (a). Comparison of the mean values of productive and reproductive traits in different genotypes of cattle

SN Parameters	SL	RS	HF	JS	AFS	AFS × PV
01. Age at puberty (days)	1143 (3)	1192.77 (3)	674.58 (2)	-	-	-
02. Length of estrus cycle (days)	21 (1)	22 (1)	20 (1)	-	-	-
03. Duration of estrus cycle (hr)	20 (1)	19 (1)	20 (1)	-	-	-
04. Age at 1 <sup>st</sup> service (days)	1174.25 (1)	-	659.33 (1)	-	-	849.0 (1)
05. Age at 1 <sup>st</sup> calving (days)	1472 (3)	1468.4 (1)	939.33 (1)	792.00 (1)	-	-
06. Gestation period (days)	281.05 (6)	279.625	276.54	276 (1)	277.47 (3)	-
07. Post-partum anestrus period (d)	249.39 (2)	-	216.4 (1)	-	165.92 (3)	152.73 (1)
08. Calving interval (days)	523.59 (7)	489.62	486.03 (4)	487.65 (1)	478.5 (3)	441.42 (1)
09. Dry period (days)	152.93 (1)	-	-	-	-	-
10. Service per conception (No.)	1.59 (3)	-	1.78 (2)	2.01 (1)	1.48 (3)	1.52 (1)
11. Lactation length (days)	315.51 (4)	293.19 (3)	359.33 (2)	268.02 (1)	344.0 (1)	305.18 (1)
12. Lactation milk yield (Liter)	2076.87 (2)	1692.05 (2)	3399.28 (1)	-	-	2223.76 (1)
13. Av daily milk yield (L/d)	4.1 (1)	3.83 (1)	8.81 (2)	-	5.8 (1)	-

( ) = No. of reports analyzed      - = No available report  
 SL = Sahiwal<sup>518,733-740</sup>      RS = Red Shindi<sup>518,733-738</sup>      HF = Holstein-Friesian<sup>518,737,741,742</sup>  
 JS = Jersey<sup>738</sup>      AFS = Australian-Friesian-Sahiwal<sup>739,740,743</sup>      AFS × PV = Pabna variety<sup>744</sup>

Table 28 (b). Comparison of the mean values of productive and reproductive traits in different genotypes of cattle

SN Parameters	RS × SL	HF × L	HF × SL	HF × RS	HF × PV	JS × L
01. Age at puberty (days)	1174.45 (2)	845.64 (19)	1072.79 (2)	1034.35 (2)	865.05 (3)	758.67 (9)
02. Length of estrus cycle (days)	22 (1)	22 (1)	-	20 (1)	-	21 (1)
03. Duration of estrus cycle (hr)	19 (1)	19 (1)	-	19 (1)	-	20 (1)
04. Age at 1 <sup>st</sup> service (days)	-	994.12 (5)	-	-	27.5 M (1)	1037.2(2)
05. Age at 1 <sup>st</sup> calving (days)	-	1219.5 (15)	1310.46 (3)	-	-	1588.59 (5)
06. Gestation period (days)	283 (1)	278 (18)	281.53 (6)	273 (1)	281.67 (2)	279.53 (13)
07. Post-partum anestrus period (d)-	-	189.55 (13)	158.01 (5)	-	139.79 (2)	291.61 (10)
08. Calving interval (days)	455.36 (2)	434.16 (27)	518.09 (6)	445.57 (2)	420.89 (2)	459.18 (12)
09. Dry period (days)	-	122.63 (8)	-	-	-	79.83 (6)
10. Service per conception (No.)	-	1.63 (22)	1.85 (5)	-	1.33 (4)	1.55 (10)
11. Lactation length (days)	344.3 (1)	294.47 (27)	297.38 (3)	349.41 (1)	248.54 (4)	260.16 (15)
12. Lactation milk yield (Liter)	1325.49 (1)	1592.79 (14)	2263.76 (2)	1427.31 (1)	1850.17 (3)	1229.67
13. Peak daily milk yield	-	-	-	-	-	-
14. Av daily milk yield (L/d)	3.80 (1)	6.66 (19)	8.47 (3)	4.42 (1)	9.11 (2)	4.60 (9)

( ) = No. of reports analyzed      - = No available report  
 RS × SL<sup>518,736</sup>      HF × L<sup>18,518,630,635,686,736-740,742,743,745-769</sup>      HF × SL<sup>61,739,740,743,758,770,771</sup>  
 HF × RS<sup>518,736</sup>      HF × PV (Pabna variety)<sup>39,744,771,772</sup>      JS × L<sup>518,686,718,731,736,738,745-750,755-757,763,769,773-775</sup>

Table 28 (c). Comparison of the mean values of productive & reproductive traits in different genotypes of cattle

SN Parameters	SL × L	RS × L	RS × PV	SL × PV	RCC
01. Age at puberty (days)	882.60 (15)	1077.43 (12)	1005.62 (1)	1037.85 (5)	961.33 (12)
02. Length of estrus cycle (days)	-	21 (1)	-	-	-
03. Duration of estrus cycle (hr)	-	20 (1)	-	-	-
04. Age at 1 <sup>st</sup> service (days)	-	971.03 (3)	-	-	-
05. Age at 1 <sup>st</sup> calving (days)	1388.90 (10)	1505.6 (10)	1416.62 (1)	-	1229.51 (9)
06. Gestation period (days)	280.79 (18)	279.18 (13)	283.87 (1)	282.37 (4)	280.88 (18)
07. Post-partum anestrus period (d)	114.90 (16)	142.45 (11)	-	124.43 (4)	89.51 (11)
08. Calving interval (days)	452.35 (19)	463.44 (15)	571.81 (1)	442.37 (2)	447.13 (18)
09. Dry period (days)	138.47 (7)	168.8 (4)	-	-	165.99 (3)
10. Service per conception (No.)	1.68 (18)	1.82 (12)	-	1.35 (5)	1.5 (16)
11. Lactation length (days)	276.40 (22)	269.02 (15)	317.97 (1)	224.86 (5)	243.96 (16)
12. Lactation milk yield (Liter)	158.73 (12)	1215.62 (7)	2116.91 (1)	1550.88 (4)	539.15 (12)
13. Av daily milk yield (L/d)	4.37 (18)	3.59 (12)	-	7.39 (4)	2.24 (13)

( ) = No. of reports analyzed      - = No available report  
 SL × L <sup>34,44,518,630,634,733,736,745-751,755-757,759-761,763,768-770,773-775</sup>      RS × L <sup>44,518,630,733-736,745-753,755,756,759,761,768,769</sup>  
 RS × PV <sup>733-735</sup>      SL × PV <sup>39,492,771,772,776</sup>      RCC <sup>11,43,44,588,630,636,732-735,737,755-757,777-784</sup>

Table 28 (d). Comparison of the mean values of productive and reproductive traits in different genotypes of cattle

SN Parameters	PV	DV	MV	NBG	DDC	CB	Local
01. Age at puberty (days = d)	1093.85 (4)	-	1013.4 (1)	869.1 (1)	572.4 (1)	1283.78 (4)	1028.98(17)
02. Length of estrus cycle (d)	21 (1)	-	-	-	-	-	22 (1)
03. Duration of estrus cycle (hr)	22 (1)	-	-	-	-	-	21 (1)
04. Age at 1 <sup>st</sup> service (d)	-	-	-	-	-	-	2290 (6)
05. Age at 1 <sup>st</sup> calving (d)	2323.9 (1)	-	1365.6 (1)	1190.7 (1)	-	1117.95 (3)	1355.77 (21)
06. Gestation period (d)	281.94 (7)	284.88 (1)	310.2 (1)*	280.8	275.8 (1)	281.73 (3)	281.76 (22)
07. Post-partum anestrus period (d)	135.16 (5)	-	70.26 (1)	109.72 (1)	-	227.5 (4)	130.99 (23)
08. Calving interval (d)	462.61 (4)	524.0	399 (1)	441.94 (1)	-	456.2 (7)	464.18 (27)
09. Dry period (d)	228.2 (1)	-	72.6 (1)	180.0 (1)	190.0	104.33 (6)	171.26 (9)
10. Service per conception (No.)	1.37 (8)	-	1.3 (1)	1.36 (1)	1.62	2.13 (6)	1.52 (28)
11. Calving to 1st service (d)	-	-	-	-	-	119.38 (3)	140.43 (7)
12. Highest milk production (L/d)	-	-	6.68 (1)	-	-	10.4 (2)	2.40 (2)
13. Lowest milk production (L/d)	-	-	-	-	-	2.92 (2)	0.72 (2)
14. Lactation length (days)	261.48 (9)	336.43 (1)	253.5 (1)	218.58 (1)	240 (1)	262.88 (9)	239.20 (35)
15. Milk yield (L/lactation)	1276.11 (6)	2205.43 (1)	1727.36 (1)	-	-	1290.69 (5)	669.61 (15)
16.. Av daily milk yield (L/c/d)	4.27 (5)	-	6.8(1)	3.46 (1)	1.70 (1)	6.27 (8)	2.39 (32)

( ) = No. of reports analyzed      - = No available report      PV <sup>39,44,492,518,630,733,734,771-773,785,786</sup>  
 DV (Dhaka variety) <sup>733,734</sup>      MV (Munshiganj variety) <sup>787</sup>      NBG (North Bengal Grey) <sup>14</sup>  
 DDC (Dinajpur dwarf cattle) <sup>12</sup>      NICB (Non-identified crossbred) <sup>495,582,630,642,763,788-794</sup>  
 Local (Indigenous, Native, Zebu, Non-descriptive) <sup>18,34,36-38,322,485,495,518,582,630,635,642,736-741,746,748,749,751,754,758-761,763-767,774,788,791-803</sup>

### **Age at puberty in heifers**

Puberty is defined in heifers as the time when they first ovulate and show an estrus or heat period. Puberty is a period at which sexually organs functionally developed and animals become able to release the gametes by first ovulation.<sup>804</sup> Puberty is also defined as when ovulation is accompanied by visual signs of estrus and subsequent normal luteal function.<sup>805</sup> Although puberty and initiation of normal estrous cycle are complex events that require maturation of the hypothalamic-pituitary-ovarian axis, it has been well documented that nutrition, age and genetics are regulators of age at puberty.<sup>805</sup> Tables 28a-d show that the mean values of age at puberty in heifers varied from 572.4 days (19.08 months) in Dinajpur dwarf cattle to 1283.78 days (42.79 months) in non-descriptive crossbreds heifers. These mean age at puberty reported in different genotypes of heifers found highest in comparison to the reported standard values. Heifers must reach puberty by 13 to 14 months of age to calve as two years age, however it is influenced by age, weight, hormone, genetic (breed), nutrition and environment of heifers.<sup>806</sup> New modern hormonal technologies, proper management, housing, feeding system of the heifers can reduce the age of puberty and sexual maturity.<sup>804</sup>

### **Length of estrous cycle in cows**

Estrus in cattle is commonly referred to as heat. The estrous cycle of the cow is the period from one estrus (heat) to the next estrus which is usually averages 21 days with a range of 18 to 24 days. Tables 28a-d show an average length of estrus cycle 20 days in Holstein-Friesian and HF × RS, 21 days in Sahiwal, JS × L, RS × L and Pabna variety, 22 days in Red Sindhi, RS × SL, HF × L crossbred cows.

### **Duration of estrus in cows**

The average duration of standing heat is 15 to 18 hours but heat duration may vary from 8 to 30 hours in cows. Estrus is short in cow, with ovulation occurring 10 to 12 hours after the end of estrus. The best conception rates occur if AI is carried out in the middle to the end of standing estrus i.e. 13 hours before to 8 hours before ovulation, about 30 hours after the onset of estrus. The average values on the duration of estrus in cows reported as 19 hours in Red Sindhi, HF × L, HF × RS, RS × SL, 20 hours in Sahiwal, HF, JS × L, RS × L 21 hours in local cows and 22 hours in Pabna variety (Table 28a-d).

### **Age at first service in heifers**

Tables 26 a-d show that the mean values of the age at first service in heifers of different genotypes reported in Bangladesh varied widely from 659.33 days in HF to 2290 days in local non-descriptive heifers. However, the standard target age for the age at first service has been suggested to 18 months, an age when heifers are expected to reach around 300kg for Holsteins and 275 kg for crossbreds.<sup>807</sup>

### **Age at first calving in heifers**

The world cattle farming practice has adopted first breeding of heifers at 15 to 18 months of age with calving between 24.5 to 27.5 months as a model with optimum economic profit.<sup>808</sup> Analysis on the published reports on age at first calving in different genotypes shows comparatively lower age at first calving in AFS (792 days) and HF (939.33 days) than other

genotypes especially highest in Pabna variety (2323.9 days) (Table 28a-d). However, 24 months has been reported as optimum age at first calving and reduction of age at first calving to 24 months of age suggested to be an effective management practice.<sup>809</sup> An optimum range of age at first calving (AFC) on dairy farms appears to be 22 to 25 months inclusive. Lower and higher than this figure can bring lower first lactation 305 days and lifetime milk yields, lower fertility and lower chances of surviving to a second lactation.<sup>810</sup> The cost of raising a heifer to 24 months of age has been reported very high and letting them stay on farm in an unproductive state for more months costs more per animal in addition to reduced milk production.

### **Gestation period in cows**

The length of the gestation period has interested farmers because a knowledge of the time to expect the birth of the calf enables proper preparation like drying off the cow and getting her in the proper physical condition for parturition and subsequent lactation. 'The period of development from the fertilization of the egg by the sperm cell until the birth of the fully developed offspring capable of independent existence outside the body of the mother is known as the period of gestation.'<sup>811</sup> Simply, gestation period is the time interval between fertilization of an egg and the birth of the young which begins at fertilization and ends with parturition.<sup>812</sup> Analyzed results reveals that the gestation period varies from 276 days in Jersey breed to 310.2 days (10.34 months) in Manikgonj variety of cows in Bangladesh (Table 28a-d). Gestation length is influenced by many factors like breeds of cows and bull, calf gender, single or multiple birth, the parity of the cow and fetal genotype but the breed of cow has the greatest influence on gestation length.<sup>813</sup> Increasing cow's age, male fetuses and growing fetus weight have been reported to contribute for prolonged gestation length in cows.<sup>814</sup>

### **Post-partum anestrus period (PPAP)**

The PPAP refers to a condition where cows have not been observed or reported in estrus for several weeks after calving, often to the end of the voluntary (elective) waiting period in dairy cattle which is the time from calving to the subsequent estrus and conception.<sup>815</sup> To maintain a 365-day calving interval, cows need to conceive on average by 83 days (60 to 90 days) after calving with gestation length 282 days when the uterus undergoes involution and preparation for the next pregnancy. Comparatively short average PPAP have been reported in Munishigonj variety (70.26 days; single report) and Red Chittagong (89.51days; 11 reports) cows than other genotypes of cattle with especially highest PPAP in JS × Local crossbred (291.61 days) cows (Table 28a-d). The causes of the post-partum anestrus in cattle are often multifactorial but can be broadly categorized into physiological, nutritional, managerial, environmental and pathological whereas suckling and nutrition (negative energy balance) are considered the most important.<sup>815,816</sup>

### **Calving interval**

Dairy cattle production is characterized by cycles of calving, lactation including gestation and a dry period followed by the next calving. The term 'calving interval' refers to the period from one calving to the next calving from the same cow. The optimum calving interval seems to be somewhere between 12 and 14 months. There is general agreement that 12 months represents a

short calving interval based on pregnancy period of 280 days and a non-pregnancy period of 85 days. Comparatively highest calving interval have been reported in HF  $\times$  SL (518.09 days) and RS  $\times$  PV (571.81 days) crossbred cows than other genotypes especially found lowest in MV (399 days) in Bangladesh (Table 28a-d). However, the breed means for first calving interval across time ranged from 390 days for Jerseys to 407 days for Brown Swiss.<sup>817</sup>

### **Dry period in cows**

The dry period is the period before calving that cows are not milked which is traditionally 6 to 8 weeks. The main functions of the dry period are to treat the cow with antibiotics in case of persistent sub-clinical mastitis, to allow the cow a rest period before birth of the next calf and to minimize milk yield in the next lactation. The udder of dairy cow requires a non-lactating or rest period, prior to calving in order to regenerate their mammary gland and optimize milk production in the subsequent lactation. This phase of the lactation cycle is commonly referred to as the dry period. Analysis of the findings on dry period in the different genotypes of cows reveals lowest length of dry period in MV (72.6 days) and JS  $\times$  L (79.83 days) crossbred cows in comparison to other genotypes (Table 28a-d). The dry period of the dairy cows lactation cycle ranges from 45 to 60 days in length.<sup>818</sup> Numerous studies demonstrated that a 60-day dry period is optimum and a dry period less than 40-day reduces milk yield in the subsequent lactation.<sup>819</sup> The cow and her udder are prepared for the next lactation during dry period, hence any abnormalities during the dry period will have a negative effect on the cow's health and milk production after calving. However, the dry period of 40 to 80 dry days provided maximum performance in Holstein cows.<sup>819</sup>

### **Number of services per conception (NSPC)**

The NSPC is frequently used as an indicator of fertility and the optimum value is considered to range between 1.6 and 1.8 and NSPC around 2 is still acceptable.<sup>820</sup> Out of the 24 genotypes of cattle investigated for the NSPC reveals that except two genotypes JS (2.01) and non-descriptive crossbred (2.13) all the 22 genotypes required less than 2.0 NSPC (Table 28a-d). Responsible factors for NSPC are the quality and quantity of semen, accuracy of heat detection, time of insemination and skill of the inseminator, level of fertility, season of the year and environment factors. Factors like cattle breed, lactation number, AI number and sire breed are the most important factors to get maximum conception rate of the cows.<sup>821</sup>

### **Lactation length (LL) and lactation milk yield (LMY)**

The standard LL of 305 days has been selected because this is approximately the normal lactation length of cows calving at interval of 12 months. However, in tropical regions, restricting the lactation records to 305 day would have less effective, as few cow's milk more than 305 days.<sup>822</sup> Analysis of findings on LL and LMY of the different genotypes of cows reveals that the average highest LL of 359.33 days in HF cows with highest LMY of 3399.28 liters and lowest LL found in NBG cows (218.58 days), whereas the average lowest LMY reported in SL  $\times$  L crossbred (158.73 liters) cows (Table 28a-d). When the results on LL and LMY analyzed based on the crossbred between Pabna varieties with different exotic genotypes found highest LMY in AFS  $\times$  PV (2223.76 liter) in 305.18 LL (Table 28a-d). These findings

are in conformity with individual report of highest LMY reported in AFS × PV (1632 liters) in 282.80 days LL in comparison to PV (1503 liters), HF × PV (1619 liters), JS × PV (1517 liters) and SL × PV (1548) cows.<sup>823</sup>

### Daily milk yield in different genotypes of cows

Tables 28a-d show that the comparatively highest average daily milk yield by HF (8.81 L/d) followed by AFS (5.8 L/d), SL (4.1 L/d) and RS (3.83 L/d) of the exotic breeds of cows. These analyzed findings are also in support the individual report of the CCBSDF where 11.57 liter/day milk yield reported in HF cow followed by AFS (4.68 liter/day).<sup>824</sup> The HF crossbred with PV produced highest daily average milk yield (9.11 L/d) in comparison to HF × SL (8.47 L/d), HF × L (6.66 L/d) and HF × RS (4.42 L/d) whereas the non-descriptive crossbred produced milk 6.27 L/day (Table 26d). Among the local varieties of cows, highest average daily milk yield reported in MV (6.8 L/d) variety in comparison to other local varieties (Tables 28a-d). Comparatively highest daily milk yield has been reported in H × L (3.29 L/d) than JS × L (3.08L/d), SL × L (2.84 L/d), SD × L (2.99 L/d) and RCC (2.46 L/d).<sup>756</sup>

### Seasonal influence on the occurrence of estrus in cows

Table 29 shows that the estrus occurs throughout the year in all the seasons but higher in rainy season in comparison to other seasons in the Rajshahi Government Dairy Farm whereas it occurs at the similar percentage in the BLRI Cattle Breed-1, Savar. The seasonal variation on the occurrence of estrus with higher in summer than in winter which positively correlated with environmental temperature and insulation duration whereas negatively correlated with rainfall in Holstein cows have been reported elsewhere.<sup>825</sup>

Table 29. Seasonal influence on the occurrence of estrus and conception in indigenous cows maintained under farming conditions					
SN Season	Rajshahi Government Dairy Farm (Study period 1986-1987) <sup>826</sup>			BLRI Cattle Breed-1 (BCB-1)2 (Study period 1992-2006) <sup>485</sup>	
	No. of cows	Estrus No. (%)	Conceived No. (%)	SN Season (month)	Estrus cows No. (%)
1. Winter (Dec-Feb)	71	42 (59.15)	20 (47.62)	1. Winter (Oct-Jan)	384 (27.39)
2. Summer (March-May)	62	37 (59.68)	19 (51.35)	2. Summer (Feb-May)	517 (36.88)
3. Rainy (June-August)	35	23 (65.71)	13 (56.52)	3. Rainy (June-Sept)	501 (35.73)
4. Autumn (Sept-Nov)	26	09 (34.62)	06 (66.67)	-	-
<b>Overall</b>	<b>194</b>	<b>111(57.22)</b>	<b>58 (52.25)</b>	<b>Overall</b>	<b>1402</b>

The influence of parities on productive and reproductive performance of native cows under farm condition have been reported.<sup>827</sup> There are some differences on daily milk yield, lactation length, birth weight of calves, post-partum anestrus period and gestation length but no differences on the calving interval and number of services per conception have been reported in native cows.<sup>827</sup>

Genotype (breeds) has a significant effect on biological efficiencies of dairy cows.<sup>475,828</sup> Performance of the Holstein Friesian breed and its crosses with local cows especially PV and

MV has been reported highest productive performance among all the investigated genetic groups in Bangladesh. Among the cross-bred, the F2 and subsequent generations have reported inferior than the F1.<sup>737</sup> However, the pure exotic breeds especially HF has been reported not suitable in tropical environment in Bangladesh and moreover it requires low temperature, better feeding and management and less resistant to diseases and parasites. Accordingly cross-bred (HP × L) cows have been suggested to rear under Bangladesh environmental conditions.<sup>829,830</sup>

### **Estrus and pregnancy diagnosis in dairy cattle**

The AI is the most viable option to produce pregnancies in dairy cows but implementation of a successful AI program on dairy cattle requires accurate and efficient detection of estrus. Several significant physiological changes have been reported to occur during the peri-estrous period that enables detection of estrual behavior and other correlated traits in cows. Some of these changes include physical activity, vaginal cytology and pH, electrical resistance of vaginal mucus and genital tissues, body temperatures, pulse and heart rates, blood flow, rumination time, pheromones, blood metabolites and hormones, milk yield and feed intake.<sup>831,832</sup> Cows are monitored traditionally for visual signs of estrus such as 'standing to be mounted' by a herd mate but it is difficult to monitor several times in a day and identify when to inseminate.

Methods of estrus detection that are widely used on farms do not have good rates because the physiological and behavioral changes of the animals as well as the period of the duration of estrus cycle are being expressed in low intensity and short duration and even they are very variable and difficult to measure. Accordingly, the use of electronic methods have been suggested to improve estrus detection.<sup>833</sup>

Return to estrus from 18 to 24 days after AI is often considered by dairy farmers the easiest and least costly method for determining non-pregnancy in dairy cattle early post breeding. Estrus detection efficiency is estimated to be less than 50% dairy herds which is likely a result of the short duration of estrus behavior reported for lactating cows housed in concrete flooring in common housing system. Estrus cycle duration varies widely among lactating dairy cows from the standard 21-day interval and averaged around 24 days with a high degree of variability among animals inseminated lactating dairy cows.

Pregnancy examinations are primarily used to identify pregnancy and non-pregnancy status of inseminated or mated females cattle, so that non-pregnant cows can be managed and reinseminated to reduce inter-insemination and calving intervals. Additional benefits are the detection of uterine or ovarian abnormalities, diagnosis of twins and others.<sup>831</sup> Rectal palpation, ultrasonic diagnosis, progesterone diagnosis, early pregnancy factor diagnosis, diagnosis using pregnancy-associated glycoproteins, diagnosis using activity and temperature have been described.<sup>831</sup> Early pregnancy diagnosis is crucial to shortening the calving interval through enabling the farmers to identify open animals so as to treat and /or rebreed them at the earliest opportunity. However, several methods of pregnancy diagnosis are being practiced in bovine species, yet none qualifies as the ideal pregnancy diagnosis methods due to the inherent limitations of sensitivity, accuracy, specificity, speed and ease of performing the test. **Table 30** shows the summary on the research findings on the estrus and pregnancy diagnosis in cattle of Bangladesh.

Year	Research objectives	Major findings	References
1974	To evaluate the methods of diagnosis of pregnancy in dairy cows	Presence of keratinized epithelial cells in the mucus of cows has been suggested pregnancy but no such distinct results obtained with chemical tests of urine of pregnant animals.	834
1975	To detect estrus and pregnancy based on mucus examination	The presence of cornified epithelial cells in mucus has been reported as estrus in animals. The normal type of estrus could be detected by examination of the mucus before AI.	835
1987	To evaluate Dip-stick ELISA to detect estrus & pregnancy in dairy cows	Milk samples of 460 cows have been analyzed with Dip-stick ELISA (Progestassay <sup>®</sup> Pitman-Moore Inc, USA), of which 378 cows found estrus & AI and 304 cows became pregnant.	836
1987	To assess the serum cholesterol to detect reproductive status of dairy cattle	The serum cholesterol level of pregnant, lactating non-lactating cows showed significantly higher than calves and heifers but highly significantly decreased in cows with retained placenta.	837
1994	To detect true estrus and early pregnancy in zebu cows by using radioimmunoassay in milk & plasma	Estrus plasma and milk samples demonstrated low progesterone (0.99 and 2.02 mmol/L) in 91% and 90% cases, respectively. Progesterone assay at 24 days after estrus may be accurate for early diagnosis of pregnancy in zebu cows.	838
2017	To measure the vaginal electrical impedance (VEI) to detect estrus in dairy cows	Approximately 40% cows remained un-detected when they are in estrus. A satisfactory CR can be achieved only if the AI is performed at the correct time relative to ovulation. The VEI could be used to detect estrus but daily VEI values are required to confirm the stages of estrus cycle, correct time of AI and early pregnancy.	839
2017	To detect the electrical resistance of vaginal mucus (ERVM) during estrus to determine the best time of AI	The ERVM values up to 220 $\Omega$ during estrus has been reported to be the best for AI with higher CR than that of more than 220 $\Omega$ . The Draminski electrical heat detector has been suggested to use for proper detection of time of AI in cows.	840

### Research on commercial dairy farms

The productive and reproductive performances of both the smallholder and commercial dairy farms have been analyzed (Tables 28a-d) and evaluated.<sup>841-843</sup> Analysis of data of 25 commercial dairy farms in the districts of Dhaka and Gazipur suggested that the dairy farmers have ample opportunities to increase output by using more of concentrate feed and labor inputs.<sup>788,842</sup> A survey of 30 commercial dairy farms in CTG showed that 57% farm owners belong to business class and the remaining 43% to different categories. Of the business categories, 53% considered dairying as a side-business whereas 47% considered it as a main business enterprise.<sup>788</sup>

### Constraints of dairy farms

Dairy farming both private and commercial have been reported to be an important and have the potential to poverty alleviation, food security, improved family nutrition, income and

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employment generation. However, inadequate veterinary medical services, scarcity of feed and fodder, high price of concentrates and drugs, unpredictable milk market, low milk price, lack of grazing land, long distance of AI center and low conception rate (CR), lack of credit facilities, natural hazards, calf mortality and diseases of dairy cattle and lack of extension services especially on technical knowledge have been recognized as major constraints limiting dairy production in Bangladesh.<sup>238,615,638,651,659</sup>

The major constraints of the smallholder dairy farmers for rearing dairy cattle have also been reported in terms of percentage and rank basis (Table 31). In addition, problems of dairy farms have also been expressed as high problems (69.0%), medium problems (31.0%), scarcity of feeds and fodder (99.0%), disease problem (79.0%), calf rearing problem (42.0%) and inability to adopt AI (33.0%).<sup>847</sup>

Table 31. Major problems faced by the dairy farmers (farmers' opinion in %) in Bangladesh							
SN Recorded problems of dairy farms	Ref- <sup>238</sup>	Ref- <sup>651</sup>	Ref- <sup>638</sup>	Ref- <sup>844</sup>	Ref- <sup>631</sup>	Ref- <sup>845</sup>	Ref- <sup>846</sup>
01. Diseases	+	-	94.0	-	-	-	-
02. Deficiency	-	-	78.0	-	-	-	-
03. Scarcity of feeds and fodder	89-100	54.0	72.0	+	90-100	80.0	89.29-100
04. Lack of knowledge to dairy farms	-	-	-	+	-	-	-
05. Inadequate veterinary services	64-92	86.0	-	+	58-95	66.67	-
06. Non-availability of grazing land	79-90	50.0	-	+	70-96	67.67	-
07. Non-availability of hybrid bulls	26-82	-	-	-	40-64	-	-
08. Non-availability of hybrid dairy cattle	76-85	-	-	-	-	45.00	-
09. Long distance of AI center	20-70	-	83.0	-	30-45	-	-
10. Low conception rates of AI	30-74	-	83.0	-	-	-	-
11. Lack of knowledge of disease	-	-	-	+	-	-	-
12. Inadequate complex loan facilities	31-62	34.0	-	+	-	-	-
13. Insurance system	-	-	39.0	-	-	-	-
14. Lack of training & extension services	24-56	-	-	+	27-50	47.00	-
15. Lack of capital	-	-	-	+	75-85	-	-
16. Non-organized milk marketing	83-96	-	11.0	+	40-60	-	-
17. Low milk yield	-	-	51.0	-	-	-	-
18. Low price of milk	-	84.0	-	-	-	-	-
19. Non-availability of milk processing	-	-	30.0	-	-	-	-
20. Natural hazards (rainfall, storm etc.)	-	44.0	14.0	-	-	-	-
21. Calf mortality	10-30	-	63.0	-	20-35	-	-
22. Adult cattle mortality	-	-	27.0	-	-	-	-
23. Non-availability of vaccine	-	-	72.0	-	-	-	-
24. Skilled labor	-	-	57.0	-	-	-	-
25. Security	-	-	44.0	-	-	-	-
+ = Recorded as problems							

The loan provided to the dairy farmers have been reported to have a positive impact on the development of dairy industries especially to increase the number of dairy animals, milk production and labor employment.<sup>712</sup> It appears that only 6% farmers received services of AI, 32 for vaccination and 22% surgery and obstetrics services, however, the dairy farms located around Upazila headquarter received better service than located at long distance.<sup>848</sup> Improved

feeding technology, proper hygienic and sanitation program, proper treatment, sound breeding policy should be taken and more participation in management practices are necessary for increasing milk production as well as establishing dairy enterprises.<sup>640</sup>

### **Research findings on milk and milk products**

Billions of people consume milk and milk products every day in the world. Milk is a composite physiological fluid of most complete food and dairy products are considered to be the most nutritious foods of all. Children and adolescents should be encouraged to consume milk and milk products because calcium of milk is required for bone development and maintenance.

Dairy industry in Bangladesh has been transforming from traditional substance to more market-oriented and enterprise-driven approach in the milk production system which would open the opportunity for dairy farmers to exploit the rising demand of milk and milk products at national level.<sup>849</sup> Bangladesh has milk production of 9.92 million tons in 2018<sup>17</sup> whereas the Integrated Dairy Research Network (IDRN) estimated for 2018 as 7.98 million tons.<sup>850</sup> The milk availability per capita is reported as 165.07 ml/day/head against the minimum requirement of 250 ml/day/head.<sup>17</sup> The self-sufficiency according to DLS is 64% while the same is 53% according to IDRN.<sup>850</sup> Only 9.0% of the total milk production is delivered to the processors and the remaining 91% is traded as informally.<sup>850</sup> The maximum milk production in 2030 will be 13.6 and 18.1 million ton as forecasted by the IDRN and DLS, respectively. Both data sources might be overestimated for the milk production which can be tested by taking backward validation and use appropriate methods and models for forward estimation which in turn will help for increasing the precision of the data.<sup>851</sup>

Milk production trend of Milk-vita through the year,<sup>660</sup> lactation curves of different cattle breeds<sup>823</sup> and lactation and stage difference in milk yield<sup>852</sup> have been reported from Bangladesh.

Seasonal influence has been recognized as one of the factor on milk production and milk fat content in dairy animals in Bangladesh. Higher milk production has been reported during January (40.94%) and February (41.13%) and lower for July (20.47%), August (17.84%), September (18.59%) and October (18.87%) in Baghabarighat milk shed area,<sup>853</sup> whereas highest milk production has been reported in the month of June and lowest in January, August, September and December in the Sree-Nagar Milk Shed area and these differences have been explained to be associated with the availability of forage.<sup>854</sup> The first month of lactation reported as best milk producing period among the five months and the management system had positive association with milk composition of local Pabna cows.<sup>42</sup>

### **Composition of milk**

The physiochemical properties of different packaged fluid milk,<sup>855</sup> effect of feeds on the composition of milk,<sup>856</sup> compositional profile of milk<sup>857</sup> and physical, chemical and microbiological quality of cattle and buffalo milk<sup>858</sup> have been reported from Bangladesh. Milk composition is subjected to change in response of genetics, breeding, feeding, number and stage of lactation and health status of the lactating animals.<sup>859</sup> Significantly higher fat, protein and total solids in milk of RCC have been reported in comparison with the milk of cross-bred (HF cross, Jersey cross & Sahiwal cross) cows,<sup>860</sup> even milk of RCC showed best data both from nutritional and technological aspects.<sup>859</sup>

## Cattle production, management and dairy products

The milk production and its composition in local cows have been reported as 1.5 liter/ day, fat 4.59%, SNF 8.91% and total solids 13.49% in early days<sup>861</sup> and differences between cow milk and buffalo milk has also been reported.<sup>858</sup> Recently, several reports have been published on different aspects on bovine milk composition milk (Table 32).

SN	Constituents	SL × SD (n = 76) R <sup>633, 860</sup>	Sindhi (n = 19) R <sup>633</sup>	RCC (n = 60) R <sup>633, 862, 860, 859</sup>	HF × L (n = 45) R <sup>859, 860, 862</sup>	J × L (n = 12) R <sup>860</sup>	Local (n = 15) R <sup>859</sup>
01.	TMY, kg	1680.33(2)	1620.67	1630.46 (1)	-	-	-
02.	Acidity, %	0.118 (1)	-	0.165 (1)	0.145 (1)	0.146	-
03.	Specific gravity	1.028 (1)	-	1.029 (2)	1.029 (2)	1.032	-
04.	Water, %	-	-	854.0 (1)	-	-	-
05.	Total solids, %	13.16 (1)	-	14.40 (2)	12.1 (2)	14.2	-
06.	SNF, %	8.46 (2)	8.480	8.35 (3)	8.02 (2)	9.57	-
07.	Milk fat, %	4.10 (2)	4.709	6.05 (3)	4.28 (1)	5.20	-
08.	Protein, %	3.92 (2)	3.767	4.04 (3)	3.11(1)	3.82	-
09.	True protein (g/kg)	-	-	37.80 (1)	27.15 (1)	-	36.40
10.	Casein (g/kg)	-	-	28.83 (1)	18.38 (1)	-	27.14
11.	Whey protein (g/kg)	-	-	8.96 (1)	8.77 (1)	-	9.26
12.	NPN (g/kg)	-	-	0.36 (1)	0.36 (1)	-	0.35
13.	Lactose (g/kg)	-	-	52.65 (1)	45.95 (1)	-	50.55
14.	Glucose (mg/kg)	-	-	20.62 (1)	7.55 (1)	-	20.45
15.	Galactose (mg/kg)	-	-	57.35 (1)	42.69 (1)	-	58.43
16.	Total minerals (g/kg)	-	-	8.53 (1)	7.17 (1)	-	8.43
17.	Calcium (g/kg)	-	-	1.40 (1)	1.09 (1)	-	1.32
18.	Phosphorus (g/kg)	-	-	1.14 (1)	0.81 (1)	-	1.08
19.	Ca : P ratio	-	-	1.23 (1)	1.35 (1)	-	1.22
20.	Magnesium (g/kg)	-	-	0.12 (1)	0.09 (1)	-	0.12
21.	Sodium (g/kg)	-	-	0.40 (1)	0.48 (1)	-	0.40
22.	Potassium (g/kg)	-	-	1.52 (1)	1.52 (1)	-	1.61
23.	Manganese (g/kg)	-	-	0.06 (1)	0.06 (1)	-	0.06
24.	Zinc (mg/kg)	-	-	5.03 (1)	3.49 (1)	-	4.78
25.	Copper (mg/kg)	-	-	0.07 (1)	< 0.05 (1)	-	< 0.05

SL × SD = Sahiwal × Sindhi

J × L = Jersey × Local

SNF = Solid not fat

n = No. of samples (cows) tested

RCC = Red Chittagong cattle

- = Data not available

NPN = Non-protein nitrogen

( ) = No. of reports

HF × L = Holstein-Friesian × Local

TMY = Total milk yield

R = Reference

The highest fat % has been reported in RC cows than Jersey and Sahiwal crosses and lowest in HF crosses cows. The highest protein value observed in RC cows and the lowest in HF crosses. Comparatively higher total solids (14.81% vs. 12.97) and fat (6.17% vs. 4.92%) have been reported in Pabna variety cows reared on station (BLRI) than rural community which might be due to concentrate supplement to cows maintained at BLRI station.<sup>42</sup> The physiological condition of the animals and quality of milk may be evaluated based on milk metabolites. Four

metabolites ( $\alpha$ -keto glutaric, orotic, succinic and formic acid) in milk of Holstein cross cows, three in milk of RC cows ( $\alpha$ -keto glutaric, succinic and uric acid) and two (citric and  $\alpha$ -keto glutaric acid) in milk of indigenous cows have been reported.<sup>863</sup> All the animals species and breeds showed considerable variation regarding the major components in milk. RCC and Deshi cow's milk are more favorable because of their higher true protein, casein, lactose, and total mineral content. The indigenous cattle milk is more or less similar to RCC milk regarding all most all the milk components.

### **Evaluation of the quality of raw milk**

Milk is one of the most complete nutritious foods for humans considered to be the 'ideal food' because it is rich in nutrients essential for growth and maintenance of a healthy life of all ages especially more importance for the infants. Due to presence of most of the nutrients for health in milk, it acts as an ideal growth medium for bacterial pathogens that cause spoilage of milk. The evaluation of the quality of milk mostly includes somatic cell count (SCC), micro-biological count (MC) and chemical composition mainly protein and fat contents. Milk from a healthy udder may be sterile or contains very low level of bacteria, usually  $10^2$  to  $10^3$  cfu/ml of milk but the addition of microbes due to contamination during milking process and growth will reduce the time required for milk to spoil. The udder and teat (udder interior & teat exterior), environment and the milking and milk handling equipment are the three main sources of microbes of contamination of raw milk. Most of the raw milk samples have been reported to be contaminated with bacteria associated with human health risk in Bangladesh.<sup>864-866</sup> Antibiotic resistance bacteria isolated (*Staphylococcus aureus*, *Escherichia coli*) from raw milk samples have been reported from Bangladesh.<sup>867</sup> The main sources of microbial contamination of raw milk are the infected udder and teat canal, surface of the teat skin, surrounding air, housing conditions, water supply, milker's hands and hygiene and equipment hygiene. The milking hygiene has been reported to have a significant effect on initial bacterial count of milk and washing and disinfection of udder and milker's hands, and sanitary rinse of milking pails just before milking with calcium hypochloride solution (200 ppm Cl) significantly improved initial bacterial quality of milk.<sup>868</sup> Accordingly, the commercial and hygienic quality of raw milk determination is required prior to reception of raw milk for further processing.<sup>869</sup> Comparison of milk constituents between market raw milk and milk from dairy farm (Table 33) and between local market raw milk and Milk-vita milk samples (Table 34) have been evaluated.

The quality of milk supplied by vendors in Mymensingh town reported inferior in comparison to milk produced in BAUDF.<sup>870</sup> Market milk samples had significantly higher % of water than the BAUDF milk samples, but total solid, solid-not-fat, fat, lactose and protein had also significantly lower in market milk than BAUDF milk samples.<sup>871</sup> The physical properties and chemical composition of milk supplied to the BAU campus from BAUDF reported to be superior to other suppliers in relation to the quality.<sup>872</sup> Raw milk samples of BAUDF found superior than the village sources of milk which may be due to maintaining better hygienic condition.<sup>873</sup>

Significantly lower all milk constituents of local market samples indicates that this market milk may be adulterated by adding water in it.<sup>874</sup> Milk collected from Baghabarighat dairy plant has reported to be superior than milk collected from other plants of Milk-vita.<sup>877</sup> The total solids, fat and protein contents of all the samples reported within the normal range except the milk fat

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SN Constituents	Market raw milk				Dairy farm raw milk				
	Mym R <sup>870</sup> (n=40)	? R <sup>871</sup> (?)	SH R <sup>872</sup> (?)	Farmers R <sup>873</sup> (80)*	BAUDF R <sup>870</sup> (n=40)	BAUDF R <sup>871</sup> (?)	BAUDF R <sup>874a</sup> (n=45)	BAUDF R <sup>872</sup> (?)	BAUDF R <sup>873</sup> (20)
01. Energy (Mj/kg)	2.47	-	-	-	3.38	-	-	-	-
02. Milk fat (g/kg)	30.4	-	-	-	47.0	-	-	-	-
03. Total solids (g/kg)	105.4	-	-	-	134.9	-	-	-	-
04. SNF (g/kg)	74.5	-	-	-	88.1	-	-	-	-
05. Acidity, %	-	0.14	0.16	-	-	0.15	0.16	0.15	-
06. Specific gravity	-	-	-	1.02635	-	-	1.031	-	1.0295
07. Water, %	-	89.95	88.72	-	-	86.21	86.33	87.73	-
08. Total solids, %	-	10.15	11.30	-	-	13.78	13.39	12.25	-
09. SNF, %	-	7.13	8.21	-	-	8.85	8.85	8.58	-
10. Milk fat, %	-	3.02	3.06	-	-	4.88	4.78	3.7	-
11. Lactose, %	-	3.78	2.86	-	-	4.66	4.64	-	-
12. Protein, %	-	2.34	-	-	-	3.51	3.57	-	-
13. Ash, %	-	0.60	-	-	-	0.71	0.71	-	-
14. TVC, CFU/ml	-	-	-	11,01979	-	-	-	-	8,33,333
15. TCC, CFU/ml	-	-	-	380.4376	-	-	-	-	317.38
16. TSC, CFU/ml	-	-	-	806.495	-	-	-	-	680.50

SH = Students' Halls (BAU)      R = Reference      - = Data not available      ? = Samples numbers not available  
 \*Four villages milk samples (Boira, Shuriakhali, Churkhali & Paglabazar)

SN Constituents	Local market raw milk			Milk vita milk samples					
	MG (50) R <sup>874b</sup>	MY (?) R <sup>875</sup>	Sherpur (29)* R <sup>876</sup>	MCC (50) R <sup>874</sup>	MCC (30) R <sup>877</sup>	TCC (30) R <sup>877</sup>	TPP (30) R <sup>877</sup>	BDP (30) R <sup>877</sup>	Pabna (400) R <sup>878</sup>
01. Acidity, %	0.160	0.1708	0.147	0.156	0.150	0.135	0.145	0.159	0.1513
02. Specific gravity	1.022	1.0286	1.030	1.032	1.024	1.022	1.024	1.027	1.029
03. Water, %	-	-	-	-	-	-	-	-	-
04. TS, % / g/kg	105.0	122.65	29.44	136.0	11.48	10.78	10.72	12.91	13.123
05. SNF, % /g/kg	15.0	84.92	85.55	88.0	7.20	6.67	7.04	7.96	8.356
06. Milk fat, %/g/kg	30.0	37.73	43.89	47.5	4.28	4.10	3.68	4.95	4.788
07. Lactose, %	-	-	44.78	-	-	-	-	-	-
08. Protein, %,g/kg	-	33.98	35.34	-	-	-	-	-	-
09. Ash, % g/kg	-	6.92	5.44	-	-	-	-	-	-
10. TVC, CFU/ml	-	-	111.44 × 10 <sup>4</sup>	-	-	-	-	-	156750
11. TCC, CFU/ml	-	-	58.89	-	-	-	-	-	316.15

MG = Manikgonj      MY = Mymensingh      MCC = Manikgonj Chilling Center      TCC= Tangail Chilling center  
 TPP = Takerhat Pasteurization Plant      BDP = Baghabarighat Dairy Plant      Ref-4! = Mean values of 5 centers  
 \*Average values of three market samples

content collected from Shombhuganj bazaar (32.66g/kg) and Mymensingh Sador bazaar (30.66g/kg) which showed less than normal level (35.0g/kg).<sup>875</sup> Moderate level of TVC and TCC in raw milk collected from local market may be due to poor hygienic milking, improper cleaning of dairy utensils and unhygienic handling during marketing of raw milk.<sup>876</sup> The qualitative and

quantitative aspects of dairy milk collected at morning and evening have been reported to be varied with that the evening milk contained higher amount of fat (4.58 vs. 5.41 %), SNF (7.75 vs. 7.81 %) and TS (12.33 vs. 13.23) but yields have reported higher at morning (52.77%) than evening (47.24%) milking except fat content.<sup>853</sup>

**Evaluation of the quality of pasteurized milk**

Pasteurized milk is a dairy milk that is heated to a specific temperature and held at that temperature for a specific duration in order to kill the harmful bacteria that makes milk safe to drink before it is packaged and shipped to grocery stores. Pasteurized milk is produced by heating milk for a minimum time of 15 second at a temperature of 72 °C or 30 minutes at a temperature of 63 °C. The post-pasteurization contamination (PPC) of pasteurized fluid milk have been reported with bacteria that are able to grow at 6 °C. Several gram-negative bacteria when introduced as PPC can grow rapidly at refrigeration temperatures around 6 °C and spoilage that can be detected sensorially within 7 to 10 days of processing.<sup>879</sup> In Bangladesh, contradictory reports on the contamination of post-pasteurization of milk have been published, in which both the commercial pasteurized and UHT milk have been considered safe for human consumption within the mentioned expiry date<sup>880</sup> whereas high count of bacteria in both the raw and pasteurized milk<sup>881,882</sup> and the TVC varied from 35500 to 1150400 in the different commercial brands of pasteurized milk have been reported.<sup>883</sup> Low levels of fat, SNF and specific gravity in the different brands of pasteurized milk samples indicates water adulteration in pasteurized milk in Bangladesh. High bacterial count including the coliforms in pasteurized milk samples may cause significant public health hazard.<sup>883</sup> Table 35 shows comparison of chemical composition between raw milk and pasteurized milk and Table 36 shows the evaluation of liquid pasteurized milk marketed packaged cow milk.

Table 35. Comparison of chemical composition between raw milk and pasteurized milk<sup>884</sup>

SNConstituents	Raw milk samples (n = 42)			Pasteurized milk samples (n = 42)		
	BAUDF	BAUSV	MDF (K)	Milk-vita	CCBS&DF	TDL
1. Milk fat (g/kg)	37.2	46.2	39.86	24.5	26.07	24.7
2. TS (g/kg)	126.29	143.20	124.41	109.11	109.59	109.14
3. Acidity (%)	0.14	0.17	0.14	0.15	0.14	0.15

BAUDF = BAU Dairy Farm BAUSA = BAU surrounding area MDF (K) = Mini Dairy Farm (Kewatkali)  
 TDL = Tulip Dairy Ltd.

The quality of milk marketed by Milk vita has been reported superior to other milk, whereas Aarong ranked second. Jahan was inferior quality in comparison to other packaged fluid milk.<sup>885</sup>

Table 36 shows that the Milk vita brand pasteurized milk maintained standard levels for chemical and bacteriological quality as per BSTI standard.<sup>886</sup> Milk brand names used in abbreviated forms but not mentioned and reported that the different brands of Bangladeshi pasteurized milk did not maintain the standard and acceptable quality.<sup>883</sup>

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Table 36. Evaluation of liquid pasteurized milk marketed packaged cow milk

SN Parameter	Milk-vita		Aarong		Tripti	Jahan	Rupali	Cowlac	Tatka	FramF	RDM
	R <sup>885</sup>	R <sup>886</sup>	R <sup>885</sup>	R <sup>886</sup>	R <sup>885</sup>	R <sup>885</sup>	R <sup>885</sup>	R <sup>885</sup>	R <sup>886</sup>	R <sup>886</sup>	R <sup>886</sup>
01. Sp. gr	1.029	-	1.027	-	1.023	1.018	1.026	1.025	-	-	-
02. pH	6.5	-	6.60	-	5.83	6.50	6.23	6.43	-	-	-
03. Acidity, %	0.17	0.166	0.15	0.157	0.15	0.09	0.15	0.14	0.136	0.141	0.169
04. Fat, %	3.53	3.51	3.10	3.41	3.54	3.30	3.70	3.36	3.06	2.26	3.33
05. Protein, %	3.39	4.07	3.46	4.03	3.14	3.08	3.56	3.18	4.14	4.14	4.10
06. Lactose, %	3.77	-	3.58	-	2.79	1.53	2.83	2.85	-	-	-
07. Ash, %	0.71	-	0.63	-	0.57	0.41	0.64	0.54	-	-	-
08. Water, %	88.51	-	89.49	-	90.16	91.89	89.47	90.37	-	-	-
09. SNF, %	7.96	8.13	7.61	8.11	6.96	5.01	6.42	6.67	8.54	8.15	8.02
10. Total solid, %	11.49	11.46	10.57	11.53	9.84	8.12	10.52	9.62	11.58	11.41	11.35
11. TCC/ml	280	10.0	360	15.00	1580	2760	1320	6780	12.80	14.40	13.40
12. TVC/ml	4.59	-	5.236	-	6.11	5.49	5.76	6.09	-	-	-
13. TSC (cfu/ml)*	-	5.4	-	6.4	-	-	-	-	5.3	6.3	6.8

\* × 10<sup>4</sup> Farm F= Farm Fresh RDM = RD Milk - = Data not available

### Ultra-high temperature (UHT) milk

There are a wide variety of microbes have been reported to be contaminated the raw milk and milk products. Raw milk can be a source of many harmful pathogens, causing a number of diseases like brucellosis, campylobacteriosis, Q fever, salmonellosis, listeriosis, tuberculosis and others. To overcome this milk borne disease problem, milk is subjected to heat treatment of various intensities like pasteurization, sterilization and ultra-high temperature (UHT). The UHT processing of milk involves heating milk in a continuous process to high temperature of 135 to 150 °C (138 °C) for a few seconds (1-8 seconds) destroys all microbes present in milk as well as inactivates all the enzymes, cooling rapidly and aseptically packaging of milk in sterile containers, thus gives the milk a better shelf-life and commercially stable. The shelf life of UHT treated milk and dairy products at ambient temperature storage is 3 to 9 months.<sup>887</sup> Very limited works on the quality of existing UHT treated milk available in the local market have been conducted in Bangladesh (Table 37).

Table 37 shows that the Starship UHT chocolate milk better and more acceptable milk followed by Milkman.<sup>888</sup> Overall acceptability UHT milk supplied by Aarong reported better, followed by Farm Fresh. However, none of the samples meet the standards of whole milk in terms of total solids, solid-not-fat and fat contents. Therefore, it is recommended that the manufacturers should standardize the raw milk during processing.<sup>889</sup>

The UHT milk of Farm Fresh have been reported to be superior than Pran Dairy and Aarong Dairy because it contained higher Total solids (119.23 g / kg), fat (34.97 g / kg), lactose (43.23 g / kg) and ash (7.0g / kg).<sup>889</sup> The quality of UHT and pasteurized milk have been reported to be excellent with the respect of parameter studied.<sup>890</sup>

The chemical quality of raw milk collected from different sources reported superior to pasteurized milk. All the raw milk samples fulfills the normal chemical composition of milk but fat and total solids content of pasteurized milk samples reported below the normal range which implies that some portion of fat has been withdrawn from the pasteurized milk. It appears that

SN Parameter	Aarong		Starship	Milkman	Pran dairy	Fram Fresh
	R <sup>888</sup>	R <sup>889</sup>	R <sup>888</sup>	R <sup>888</sup>	R <sup>889</sup>	R <sup>889</sup>
01. Flavor (50)	43.00	41.67	30.00	36.67	37.67	43.67
02. Consistency (30)	27.33	26.0	27.00	25.33	24.00	28.0
03. Color & appearance (20)	17.33	18.00	18.67	16.00	16.0	18.67
04. Specific gravity	-	1.028	-	-	1.027	1.029
05. Acidity	-	0.15	-	-	0.15	0.14
06. pH	6.53	-	6.53	6.54	-	-
07. Fat (g/kg)	17.00	34.63	17.33	20.67	34.73	34.97
08. SNF (g/kg)	123.73	84.40	124.73	123.20	82.30	84.27
09. Protein (g/kg)	32.37	34.07	32.97	32.57	32.77	33.93
10. CHO (g/kg)	83.50	-	84.33	82.50	-	-
11. Ash (g/kg)	7.87	6.73	7.43	8.13	6.73	07.00
12. TS (g/kg)	130.73	119.03	142.07	143.87	117.03	119.23
13. Lactose (g/kg)	-	43.60	-	-	42.80	43.23

the quality of pasteurized milk available in local markets is poor and consumers are not getting high quality milk.

### Bacteriological and chemical evaluation of powder milk

The physical, chemical and bacteriological assessment of market dry milk have been evaluated in Bangladesh.<sup>891-894</sup> The TVC of powder milk varied from 200,000 to 4,30,000 /g of powder milk have been reported.<sup>892</sup> No significant variation of microbial population among the different brands of infant milk food but the sanitary quality of the commercial infant milk food samples reported lower than the suggested standards.<sup>895</sup> Out of 12 full cream powder milk samples tested, of which 11 (91.67%) contaminated with *E. coli* and 6 (50.00%) contaminated with *Staphylococcus aureus* in Bangladesh.<sup>896</sup> However, no bacterial contamination has been reported in different commercial brands of powder milk that good sanitary measures have been adopted during processing and storage of milk.<sup>897</sup>

Table 38 shows a significant variation of bacterial population among the different brands of dry milk and the lower sanitary quality of the market dry milk samples suggests standard of International Commission in Microbiological Specification for Food (ICMSF). It appears that the considerably lower quality of the commercial sweetened condensed milk samples as per recommended standards of the ICMSF. Significant variations ( $p < 0.01$ ) in TVC have been reported among different brands of powder milk samples.

### Preservation and adulteration of milk

The storage of raw milk are usually performed in refrigerator, adding plant leaves, adding chemicals, heat treated (boiling, pasteurization, UHT) for preservation. The limited production of milk leads the dairy personnel to adulterate milk with unhealthy liquor and other solid substances. The way of adulteration is occurred by unhygienic milking, inappropriate transport

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Table 38. Bacterio-chemical evaluation of market powder milk in Bangladesh<sup>891,893,898-900</sup>

SN	Milk Brand	No. of samples tested	Microbial count /g				Chemical values									
			LVC	TSC	TCC	DMC	Y & M	pH	Acidity (%)	Fat (g%)	Protein (g%)	Ash (g%)	Lactose (g%)	Moisture (g%)	SNF (g%)	TS (g%)
01.	Anchor	12	5.38	4.30	3.70	7.34	-	6.80	0.13	27.89	25.87	5.48	36.64	4.11	67.10	95.89
02.	Birch tree	12	5.36	4.15	3.41	7.32	-	-	-	-	-	-	-	-	-	-
03.	Dano	12	5.30	3.48	3.60	7.32	-	-	-	-	-	-	-	-	-	-
04.	Friesian	12	6.40	4.52	3.78	7.23	-	-	-	-	-	-	-	-	-	-
05.	Kanny	12	5.63	4.00	3.70	7.20	-	-	-	-	-	-	-	-	-	-
06.	Red cow	12	5.48	3.85	3.78	7.14	-	-	-	-	-	-	-	-	-	-
07.	Blue cross	10	2.96	-	1.41	-	1.89	-	-	-	-	-	-	-	-	-
08.	Lucky boy	10	2.99	-	1.45	-	1.93	-	-	-	-	-	-	-	-	-
09.	Blue bell	10	2.93	-	1.46	-	1.96	-	-	-	-	-	-	-	-	-
10.	Danish	10	2.89	-	1.36	-	1.86	-	-	-	-	-	-	-	-	-
11.	Blue crown	10	2.83	-	1.20	-	1.83	-	-	-	-	-	-	-	-	-
12.	Blue star	10	2.91	-	1.32	-	1.85	-	-	-	-	-	-	-	-	-
13.	Kwality	03	3.53	-	-	-	-	6.73	0.13	27.89	25.22	5.46	37.41	4.02	68.09	95.98
14.	Nido	03	3.60	-	-	-	-	6.70	0.13	27.83	26.04	5.48	37.31	3.37	68.81	96.63
15.	Diploma	03	3.49	-	-	-	-	6.73	0.11	27.26	25.65	5.35	37.22	4.49	68.26	95.51
16.	Farm land	03	3.96	-	-	-	-	6.70	0.14	26.20	26.55	5.35	37.62	4.31	69.49	95.69
17.	Starship	03	3.88	-	-	-	-	6.67	0.16	26.30	27.02	5.41	37.65	3.74	70.07	96.26

TVC = Total viable count

SC = Staphylococcus count

TCC= Total coliform count

DMC = Direct Microscopic count

Y & M = Yeast and Mold

!= logarithms and in average

g% = g/100g

- = Data not available

system, germ favored storage and milk collector itself which creates milk contaminated.<sup>901</sup> The addition of water to increase volume of milk, thickening agents like starch, flour, skimmed milk powder, whey powder or other ingredients to counter the dilution and extend the solids content of the milk, vegetable oil, sugar cane or urea to compensate the fat, carbohydrate or protein content of diluted milk. Some chemicals like hydrogen peroxide, carbonates, bicarbonates, antibiotics, caustic soda and even the most lethal chemical formalin to increase the storage period of milk, ice to enhance the shelf life of milk, detergents to enhance the cosmetic nature of milk which diminishes foamy appearance and whitening of milk or calcium thioglycolate / potassium thioglycolate / calcium salts of thioglycolic acid and urea for whitening of milk and giving it a genuine look.<sup>902</sup> The quality of farm produced milk and rural milk have been reported to be deteriorated by middlemen due to adulteration with water which have been reported to be 68.0% and 54.0% of the milk samples of vendor supplied rural and vendor supplied farm milk and also added formalin preservatives respectively.<sup>903</sup> However, milk adulteration is a global concern and developing countries including Bangladesh are at higher risk associated with it due to lack of monitoring and policies that has been overlooked that can pose serious health hazard leading to fatal diseases.

Milk is being very easily adulterated throughout the world because demand and supply gap, perishable nature of milk, low purchasing capacity of customer and lack of suitable detection tests.<sup>904</sup> Adulterants in milk mainly include addition of vegetable protein, milk from different species, addition of whey and watering which are known as economically motivated adulteration which do not pose any serious health risk.<sup>905</sup> Adulterants in milk that having adverse health effects are urea, formalin, detergents, ammonium sulfate, boric acid, caustic soda, benzoic acid, salicylic acid, hydrogen peroxide, sugar and melamine. Cane sugar, starch, sulfate salts, urea and common salts are added to increase solid-not-fat (SNF). Melamine is added to increase protein content falsely.<sup>906</sup> Ammonium sulfate is added to increase the lactometer reading by maintaining

the density of diluted milk. Formalin, salicylic acid, benzoic acid and hydrogen peroxide act as preservatives and increase the shelf life of the milk.<sup>907</sup> Vegetable oil is added to increase non-milk fat in milk. Detergents are added to emulsify and dissolve the oil in water giving a frothy solution which is the desired characteristics of milk.<sup>908</sup> Table 39 shows the summery of the research findings on preservatives and adulterants added to milk and milk products in Bangladesh.

SN	Products	Methods of preservation	Results	References
01.	Ghee	Store at room temperature (RT)	Lab made ghee kept better than market ghee in aluminum container which has reported best, glass & plastic good, tinned and iron poor and earthen recorded as worst	909
02.	Ghee	Tested by BSTI- BD	All the 10 tested ghee brands have been reported to be adulterated	910
03.	Milk	Mixed morning milk with evening milk	Storage quality of milk reported better when milk stored with ice water than with or without water.	911
04.	Milk	Heat treatment	Effect of heat treatment on shelf life of milk has been reported	912
05.	Milk	Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )	0.02 to 0.04% of hydrogen peroxide reported as the suitable level for milk preservation	913
06.	Milk	Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )	Six portions of milk have been preserved with 0.01%, 0.02%, 0.03%, 0.04%, 0.05% and 0.06% H <sub>2</sub> O <sub>2</sub> . Results showed that 0.04 to 0.05% H <sub>2</sub> O <sub>2</sub> found enough to preserve milk sample up to 24 hrs	914
07.	Milk	Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )	H <sub>2</sub> O <sub>2</sub> @ 0.02, 0.04, 0.06, 0.08, 0.10, 0.12 and 0.14% of 10% solution have been added to these seven groups of Milk samples at RT (28-31 °C). The 0.14% H <sub>2</sub> O <sub>2</sub> dilution has been recommended to use for preservation of raw milk	915
08.	Milk	Banana leaf at RT	Acidity of milk dropped and it preserved milk taste, flavor and texture longer time than untreated raw milk	916
09.	Milk	Banana, water hyacinth, bamboo, date palm and jack fruit leaves	Stored at RT (24-26 °C) and the texture (14 hrs), flavor (13.33 hrs), color (17.67 hrs), taste (13.33 hrs) and acidity (12.67 hrs) of milk samples preserved with banana leaf reported better than other leaf.	917
10.	Milk	Sodium bicarbonate (0.10, 0.15 & 0.20%)	Stored at RT (32-34 °C) and reported that addition of 0.2% NaHCO <sub>3</sub> resulted optimum level for preserving milk up to 16 hours.	918
11.	Milk	Sodium bicarbonate (0, 0.3, 0.4 & 0.5%)	Preserved at RT (28-30 °C) and reported that addition of 0.5% NaHCO <sub>3</sub> suggested enough to preserve raw milk up to 19 hours	919
12.	Milk	Refrigeration (7 °C)- raw and pasteurized milk 60 °C for 30 minutes	TVC 5.915 and 4.094 log CFU/ml increased to 6.648 and 4.579 log CFU/ml and TCC 2.043 and 2.546 log CFU/ml increased to 3.070 and 2.607 log CFU /ml in raw and pasteurized milk after 10 days, respectively	920
13.	Milk	Preservatives- sodium bicarbonate & formalin Adulterants- water, cane sugar, powder milk & starch	Preservative sodium bicarbonate has been added in 20.0% milk and formalin in 10.0% milk samples without any H <sub>2</sub> O <sub>2</sub> & borax results showed that 100% milk samples adulterated with water, 26.0% with cane sugar, 14.0% with powdered milk and 12.0% with starch	921

## Cattle production, management and dairy products

14. Milk	Different containers	Effect of containers on the storage life of milk in winter season have been reported	922
15. Milk	Different containers – glass, tinned iron, plastic, aluminum, earthen and bronze at 12-20 °C and Sodium bicarbonate	Milk kept well in aluminum containers up to 10 hours but poorer in other containers and worst in earthen containers. Sodium bicarbonate @ 0.05 and 0.1% added milk kept well up to 16 hours and up to 20 hours with 0.15% based on acidity test. The Na <sub>2</sub> CO <sub>3</sub> added milk has improved the keeping quality till 24 hours of storage in aluminum containers at 10-19 °C	923
16. Milk	Adulterants- starch test & formalin test of milk	Results showed that all the tested milk samples reported negative to starch test and formalin test of collected milk samples.	924
17..Milk	Water, powder milk and formalin	Water and milk powder have been added in raw milk. In addition, formalin detected in 75% milk samples in July and 50% in sept.	925
18. Raw milk & powder milk	Shelf-life of raw milk & Dano @ 140g/L water at RT & refrigerator	Raw milk and reconstituted powder milk have been reported to be acceptable up to 9.50 and 12.0 hours at RT (27-29 °C) and 12.67 23.67 days at refrigerator temperature (5-6 °C), respectively	926
19. Milk	Adulterants of milk	Different adulteration of milk have been reported	927
20. Milk	To evaluate contamination adulteration and preservative status	High fat content even after watering and presence of formalin in 8.0% milk samples of vendor rural milk. These adulterants and preservatives in milk may cause severe public health problems.	928
21. Milk	Adulteration	Detection of adulteration of milk	929
22. Milk	To detect the quality and adulteration of raw milk	The quality of milk varied from one goalas to another as well as dairy farmers. Adulteration tests found negative in all milk samples	930
23..Milk	To detect the mixed heated and raw milk	Turbidity index has been used successfully to detect the percentage of heated milk added to raw milk	931

It appears from Table 39 that NaHCO<sub>3</sub> is the effective chemical for neutralizing the acids produced by acid producing bacteria and can be used as a short term preservation of milk under rural condition in Bangladesh where scientific cooling or pasteurization facilities are not available.

Some of the milk adulterants may produce severe public health disorders of which melamine can induce renal failure and death in infants.<sup>932</sup> Bothe peroxides and detergents in milk can cause gastro-enteritis. Excessive starch in the milk can cause diarrhea due to effects of undigested starch in colon and accumulated starch in the body may be fatal for diabetic patients.<sup>908</sup> Urea in the milk overburdens the kidneys as it have to filter out more urea content from the body.<sup>933</sup>

### Preparation of milk products

Milk is an essential basal constituent of a wide range of milk products worldwide which include liquid milk, fermented milk, cheeses, butter and ghee, condensed milk, evaporated milk, dry milk or milk powder, cream, ice cream, whey products, yogurt, curd and casein. Manufacture of table cream from reconstituted milk,<sup>934</sup> low fat-milk in the household by gravity method,<sup>935</sup> manufacture of peda from sweetened condensed milk,<sup>936</sup> use of vegetable oil in manufacture of Khulna cheese from powdered milk,<sup>937</sup> comparison of quality of khejur gur sandesh with sandesh of different sweetmeat shops<sup>938</sup> and different varieties of sweets which are

prepared from milk and marketed by the different shopkeepers in Bangladesh (Table 40). Shopkeepers of different sweetmeat shops received raw milk from farmers (52.6%) and goalas (47.4%) and highest amount of whole milk has been reported to be required per unit production of rosomalai (21.0%) and ghee (18.0%) whereas the lowest amount in chomchom (9.0%) production.<sup>939</sup> A large varieties of sweetmeats are produced in different regions in Bangladesh but some sweetmeats which are famous in Bangladesh include (a) Porabari chomchom of Tangail (b) Monda of Muktagacha, (c) Bogurar doi, (d) Pyada and Rosomalai of Comilla, (e) Kacha golla of Natore, (f) Famtala sweetmeat (Jessore), (g) Malaikari of Faridpur and Dhaka for Amrti, Jillipi and Pranhara.<sup>940</sup>

SN Sweet	Constituents	Results	References
01. Butter	Sanitary & keeping qualities of butter	The sanitary and keeping qualities of butter made from raw and pasteurized cream of different ages at 0 °C and 5 °C	941
02. Chhana	Evaluation of different coagulants on the quality of chhana	Six types of coagulants comprising of sour whey (0.5%, 1.0% acidity, citric acid (0.5%, 1.0% acidity) and blend of sour whey and citric acids (0.5%, 1.0% acidity) have been evaluated of of which 1.0% sour whey as coagulants reported best.	942
03. Rosogolla	Fresh cow milk & powder milk	Commercial powder milk has been suggested to be used for the preparation of Rasogolla to complement the shortage supply of fresh cow milk	943
04. Rosogolla	Cow milk chhana and/or soy-chhana	Rosogolla prepared from only cow milk chhana and by mixing 10% soy-chhana stored for 16 days at RT, whereas 20% and 30% soy-chhana mixed with cow milk chhana stored for 12 and 19 days respectively for human consumption	944
05. Rosogolla	Cow milk chhana and/or soy-chhana	The combination of 10% soy chhana plus 90% cow milk chhana has been suggested to produce acceptable quality of protein rich rasogolla for human consumption	945
06. Rosogolla	Cow milk chhana buffalo milk chhana & mixed chhana	Results showed that rasogolla prepared from cow milk chhana gained the highest organoleptic score, whereas 50% CMC + 50% BMC produced rasogolla nearly similar to rasogolla of CMC	946
07. Rosogolla	Flour added in chhana	For both the physical and chemical properties of rossogolla, 5% flour has been suggested to add in chhana as a binder for making high quality rosogolla. Rosogolla preparation method described.	947
08. Rosogolla	Compare the quality of rosogolla (balish) between lab prepared and collected from shop of Netrokona	Examination of physical, chemical and bacteriological status of lab made rosogolla (balish) and market products showed that the lab prepared balish found superior in comparison to the commercially available market balish collected the different sweetmeat shop of Netrokona. Preparation method described.	948

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09. Rosogolla	To assess the effect of conc of cooking and soaking sugar syrup on the quality of rosogolla	The chhana prepared by adding 1% citric acid in raw milk at 80 °C. The chhana obtained has been kneaded with 5% (w/w) wheat flour. The rosogolla prepared from 60 ° Brix cooking syrup and 40 °Brix soaking syrup kept for 24 hours resulted in the best quality rosogolla	949
10. Rosogolla	To compare the rosogolla between Lab made and market rosogolla	Lab made rosogolla has been reported to be significantly better quality than market rosogolla. The proper method, proper composition of the ingredients and strict hygiene and sanitation measures should be followed that will give the consumer satisfaction	950
11. Rasogolla	To assess the nutritional quality of rosogolla collected from branded shop	TVC, coliform and fungal counts in all the tested samples have been reported higher than the maximum permissible level of BSTI standard. About 50% samples contained <i>Salmonella</i> spp. and <i>S. aureus</i> which have public health impact	951
12. Sandesh	Cardamom powder @ 0, 0.05, 0.10 & 0.15% as preservative	Results showed that all types of Sandesh prepared with different concentrations of cardamom powder reported with good qualities in terms of physical, chemical and microbiological content	952
13. Sandesh	Cardamom powder for self-life at RT	Addition of natural cardamom powder @ 0.10% has been reported acceptable for the preparation of sandesh which has been shown more desirable aroma & increased self-life of sandesh up to 24 days	953
14. Sandesh	Cardamom powder @ 0, 0.05, 0.10, & 0.15% as preservative	Sandesh has been stored with adding different concentration of cardamom powder and stored at 23 ± 1.0 °C. Highest microbial growth has been inhibited with 0.15% cardamom powder and suggested to use as a preservative for sweetmeat to improve keeping quality	954
15. Rossomalai	Compare Milk-vita rossomalai with sweetmeat shops rossomalai	Physical, chemical and bacteriological examinations revealed that the rossomali of market sweetmeat shops reported inferior to the Milk-vita rossomali. Method of preparation of rossomalai has been described.	955
16. Rossomalai	Compare rossomalai between lab prepared & different sweetmeat shop rossomali	Physical, chemical and microbiological characteristics of rassomali prepared at lab and collected from different of sweetmeat shop from five districts have been compared revealed that the quality of different district rossomali found inferior to lab made rossomali.	956
17. Rossomalai	Compared the quality of rossomali made with cow milk and buffalo milk	Physical, chemical and microbiological quality of rossomali have been evaluated. Physical examination revealed better rossomali obtained from cow milk than buffalo milk, whereas chemical and bacteriological quality showed superior rossomali from buffalo milk than cow milk	957
18. Rossomalai	Compared the quality of rossomalai made from cow milk chhana and soy chhana	Four different types of rossomali have been prepared from cow milk with addition of 25%, 50% and 75% soy chhana. Most suitable and acceptable quality of rossomali has been reported by using admixture of 25% soy chhana and 75% cow milk chhana.	958

19. Ingrain vough	Compare the quality between lab made and collected from market of Dinajpur district	Organoleptic, chemical analysis and bacteriological status of lab made and collected from three sweetmeat shop have been evaluated. Lab made Indrani vough has been reported as best in relation to bacteriological status but Sananda sweetmeat shop's product reported superior than other two sweetmeat shop products. Preparation method has been described.	959
20. Chamcham	Compare the chamcham prepared with cow milk, buffalo milk & mixed milk	Examination of the quality of chamcham showed that chamcham prepared from buffalo milk reported superior to that of cow milk chamcham and 50% cow milk and 50% buffalo milk chamcham. Method of chamcham preparation has been described.	960

## Rossomali

Rossomali is a royal sweet often served in weddings and eaten on special occasions. The dessert is called rossomali in Bengali language, ras malai in Hindi language and rasa malei in Odia language. It is believed to have originated somewhere in Eastern Indian sub-continent, presumably in Bangladesh, Indian state of Odisha and West Bengal region. ([en.wikipedia.org/wiki/Ras\\_malai](http://en.wikipedia.org/wiki/Ras_malai)). It is a soft white round patties immersed in creamy, milky syrup flavored with cardamom, pistaias and saffron.

### Method of Rossomalai preparation<sup>955-957</sup>

- Approximately 3.0 liters of raw milk should be collected, of which about 1.80 liter milk should be boiled in a stainless pan for five minutes for preparation of chhana and remaining 1.20 liter milk should be used for malai preparation.
- The boiled milk (1.80 liter) should be cooled to 80 °C. Then the coagulant, sour whey (360 ml with 1.22% acidity) water should be added to the cooled milk for over 30 seconds allowing precipitating the milk curd (called chhana) until chhana separates.
- Whey is then removed from chhana through filtering cheese-cloth / muslin cloth and water is expelled out leaving chhana inside the cloth.
- Then 1.0% (w/w) flour is added to the chhana and it is then grinded and kneaded to prepare chhana balls (small balls of 0.5-0.75 cm size) with a smooth surface without any visible sign of cracks.
- Concentrated sugar syrup (sugar : water = 1.5 :1) is then prepared and the solution is then heated to boiling. The small ball-shaped chhana put gently in the boiling sugar syrup and cooking for 20-30 minutes. Care should be taken that the balls never over crowded the pan and there is enough space for moving them freely. After swelling the colors of the balls are slightly darken, then the cooking should be finished.
- Then sweet balls should be cooked at room temperature and filtered from sugar syrup. At that time sweet balls became large size due to osmosis activity and weight increased more than three times (1-1.25 cm).
- The 1.20 liter of whole milk, 40 g sugar and 3 to 4 pieces of cardamom should be mixed in a pan and heated until the volume is reduced by 50%. When milk turned light brown color then malai is formed.
- Balls of chhana are then cooked in hot malai for 3 to 5 minutes, cooling to room temperature (about 25 °C) for 5-6 hours and it becomes ready for human consumption.

## **Rosogolla**

The dessert is known as Rasagola in Odia and Rosogolla or Roshogolla in Bengali. Rasgulla is derived from the words 'ras' (juice) and 'gulla' (ball). Rosogolla is a sweet syrup cheese ball most popular in the regions of South Asia, manufactured from chhana which is obtained by heat and acid coagulation of milk.<sup>949</sup> It is one of the most delicious and nutritious among all sweetmeats due to its fairly high protein, fat, mineral especially Ca and P and also fat soluble vitamin A and D.<sup>961</sup>

### **Method of Rosogolla preparation**<sup>947-950</sup>

The pre-requisite for producing excellent quality rosogolla is the availability of high-quality chhana together with the binding material, kneading and concentration of sugar syrup, cooking and soaking time. The correct concentrations of cooking sugar syrup is required for the body and textural properties of rosogolla and its inappropriate concentration leads to cracked, flattened or even brushed rosogolla. Cooking is the process in which a soft and smooth body of chhana balls converts to a fluffy and fibrous network that provides spongy texture typical to rosogolla.

### **Materials**

Cow milk 3.0 liter with 4.0% fat, food grade citric acid, soft wheat flour (ACI Pure), cane sugar and cardamom

### **Methods**

#### **Chhana preparation**

- Fresh cow milk (3.0 liter) should be heated to boiling (95 °C) in a stainless steel pan for 10 minutes and then cool down up to 70-80 °C.
- The coagulants (fermented whey pH 4.2 or 1% citric acid) are then added at a temperature of 70 °C along with gentle stirring and the casein is then allowed to precipitate.
- The lumps (known as chhana) are then allowed to stay for half an hour for complete coagulation of chhana, as well as to cool down to room temperature (25-37 °C).
- Chhana is then separated from whey by filtering through a muslin cloth for 2 to 3 hours for the visible cessation of drainage of whey.
- When the loosely bound whey is completely drained out, the muslin cloth is tied together then the coagulum is hanging for about one and half an hour to complete drainage of whey.

#### **Preparation of sugar syrup**

The cooking and soaking sugar syrup @ 60 and 40<sup>o</sup> Brix concentrations have been reported to be most suitable for rosogolla making using admixture of 5% (w/w) wheat flour.<sup>949</sup>

#### **Rosogolla preparation**

- The chhana should be mixed with wheat flour (5.0% w/w) and kneaded properly to make uniform and smooth dough.
- The chhana dough is then divided into small pieces of about 10g and rolled between the palms to obtain smooth balls without cracks.
- Cooking (@ 60) and soaking (@ 40) sugar syrup are prepared separately by dissolving the requisite amount of sugar in portable water. Heavy sugar syrup containing 5% sugar (sugar : water = 1 : 1) has also suggested. A 1.5 liter sugar solution is used for cooking and 1.0 liter for soaking.
- Sugar solutions are then clarified by adding some quantity of raw milk during boiling and filtered through a muslin cloth.

- The Chhana balls are then gently dropped into the boiling syrup contained in Karahi.
- After a few seconds, the foam is formed which covered the floating balls.
- The mild temperature is regulated as the balls are constantly covered with foam.
- Some quantity of water is then sprinkled during the continued boiling of sugar syrup to maintain the sugar syrup concentration.
- It is carefully watched that balls are not over crowded in the karahi and there is enough space for moving freely, especially when they swelled.
- The heat is controlled so that the balls are constantly covered with foam.
- After a regular interval, cool water is sprinkled for keeping the sugar syrup at a controlled density.
- Complete cooking of chhana balls is accompanied 20 to 30 minutes.
- The balls are swollen to about double the original size.
- Finally, the balls are transferred to the clarified hot sugar syrup having 40% (sugar : water= 1 : 2) strength for soaking and 2 to 3 cardamom pieces are added to the sugar syrup and then cooled down to room temperature or below for 4 hours and ready for human consumption

### **Balish misti / Balish Rossogolla**

Balish misti is one type of rossogulla famous sweet of Netrokona district. This misti is pillow-shaped and looks like a pillow as kheer is coated on the top of the sweet that is why it is called balish misti.

#### **Method of preparation**<sup>948</sup>

- Approximately 3.0 liters cow milk is boiled in a stainless steel pan for 10 minutes and then is cooled at 70 °C.
- About 600 ml whey water is added in the 3 liters of the boiled milk at a temperature of 70 °C.
- Lumps of casein are formed as soon as the whey is added to the boiled milk, which is generally known as chhana.
- The contents are allowed to cool down at room temperature (about 25 °C) for 30 minutes and then the coagulum is transferred to a muslin cloth.
- When the loosely bound whey is completely drained out, the muslin cloth is tied together then the coagulum is hanging for about one and half an hour to complete drainage of whey.
- The coagulum is then carefully removed and weighed.
- The ingredients composition of Rassogolla preparation include chhana 590g + flour 75g, chhana 610g + flour 80g and chhana 595g + flour 75g can be used.
- Chhana and flour are weighed separately, mixed and kneaded.
- Then the kneaded mash should be converted into an oval shape with proper consistency to avoid the crack on the surface.
- About 3kg of sugar is dissolved in 2.5 liters of water in an iron pan and the solution is boiled.
- After some times of boiling the scum is labeled out for obtaining clean syrup.
- The syrup is kept in a suitable sized pan with a depth of 20 cm.
- The chhana of desired size (Balish) is made by hand.
- When all the Balish Rossogolla is made they are put gently in the boiling sugar syrup for cooking.

- Care should be taken that the newly prepared Rassogolla (Balish) are not over crowded in the pan and there is enough space for moving freely especially when they are swelled.
- The heat is so controlled that the rossogolla are constantly covered with foam.
- To control the density of the sugar syrup throughout the cooking period water is sprinkled at a regular interval.
- In 10-15 minutes Rossogolla are swelled and after 10 minutes of swelling the color of the Rossogolla become light are dark.
- Then the Rossogolla are allowed to stay for sometimes to become cool.
- After 3 hours Rossogolla are suitable for consumption.

### **Indrani vough**

Indrani vough is a famous sweet of the district of Dinajpur. Description of this sweet is not available in the webpage and so far only one article has been published.<sup>959</sup>

#### **Preparation of Indrani vough**<sup>959</sup>

- Approximately 3 liters raw whole milk, 200g sugar, 20g flour and 240 ml sour whey are required for the preparation of Indrani vough.
- At first 1.70 liter cow milk should be heated to boil for five minutes into two separate iron pans. The milk should be cooled to 80 °C after boiling and sour whey should be added until chhana separates.
- The contents should be allowed to cool down at room temperature (25 °C), after 30 minutes the coagulum should be transferred to a muslin cloth and the cloth should be hung for about one hour for complete drainage of whey.
- Approximately 60g of chhana is usually obtained from 1.7 liter of fresh cow milk should be broken and kneaded with flour (5.5% by the weight of chhana) in order to obtain the desired body and texture.
- Rossogolla (disc shaped) should be made without the signs of cracks.
- Concentrated sugar syrup (sugar : water = 1.5 : 1) should be made and heated to boiling.
- Just after boiling the scum should be labeled out to obtain clear syrup.
- Then Rassogolla of chhana should be cooked in the boiling syrup for 8 to 10 minutes.
- For the preparation of malai 1.30 liter cow milk should be heated in a pan until 50% volume is reduced. The rossogolla is cooked in hot malai for 3 to 5 minutes.
- Then the Indrani vough is prepared and it is allowed to stay for sometimes to become cool.
- After 5 to 6 hours Indrani vough would be ready for consumption.

### **Cham cham**

Chom chom, cham cham or chum chum is a traditional Bengali sweet, popular throughout the Indian sub-continent. This sweet comes in a variety of colors, mainly white, light pink, light yellow. The history of Porabari cham cham, an oval-shaped brownish variety of chom chom from Porabari in Tangail district in Bangladesh.

#### **Requirements**<sup>960</sup>

- Approximately 3.0 liter raw whole milk, sugar 2 kg to prepare sugar syrup, flour 40g (1.0% of weight chhana and sour whey 500 ml are required to make 1.5 kg Cham cham.

- Out of the three liters milk, two liter milk is used for chhana preparation and one liter milk is used to Mawa preparation.

### **Preparation of Chhana**

- Two liters of milk should be heated to boiling at 90 °C in stainless steel pan.
- The milk should be cooled to 80 °C after boiling and adding sour whey water at 70 °C and the lumps of casein formed are allowed to stay for few minutes for complete of chhana. The contents should be allowed to cool down at room temperature (25-29 °C).
- After 30 minutes the chhana and whey mix should be transferred to a piece of muslin cloth.
- When whey will be completely drained out, the chhana should be hung for about one hour for complete drainage of whey. Then the Chhana should be carefully removed from the muslin cloth and weighed.

### **Preparation of Cham cham**

- The mass of Chhana is then broken (grinding) and kneaded with wheat flour (1% of the volume of chhana) in order to obtain the desired body and texture.
- Small balls should be made without cracks.
- Concentrated sugar syrup (sugar : water = 1.5 : 1) should be made and heated to boiling.
- Just after boiling the scum is ladled out to obtain a clear syrup.
- Then the balls of Chhana are cooked in the boiling sugar syrup for 40 to 45 minutes, then cooled to room temperature.

### **Preparation of Mawa**

- Rest one liter milk should be boiled to dry for the preparation of mawa.
- Raw chamcham should be separated from sugar syrup, arranged on trays and mawa is then spread on the balls to garnish the chamcham.

## **Cheese**

Cheese is a dairy product which is derived from milk and produced in wide ranges of flavors, textures and forms by coagulation of the milk protein casein. It comprises proteins and fat from milk, and milk is usually acidified and adding the enzymes of rennet (or bacterial enzymes with similar activity causes the milk proteins (casein) to coagulate. The solids (curd) are separated from the liquid (whey) and pressed into final form (Wikipedia). **Table 41** shows the research findings on cheese published from Bangladesh.

Table 41. Research findings on <b>cheese</b> preparation and its quality evaluation			
Year	Constitutes	Results	Reference
1970	Dhaka cheese	Reported that about 1.2 million lbs of Dhaka cheeses are being supplied to Dhaka city from Austogram of Mymensingh district. Family profession has changed due to inadequate and high price of milk supply	962
1971	Cheese preparation method has been described	The commercial 'lactic' culture and Hensen's commercial rennet have been used for preparation of cheese. The cheese preparation method has been described.	963

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1982	Combination of cultures with use of flour produce better quality cheese	<i>Streptococcus lactis</i> alone obtained the lowest average scores (86.94%) and cheese made with <i>S. lactis</i> + <i>Lactobacillus bulgaricus</i> and <i>S. lactis</i> + <i>L. bulgaricus</i> and <i>S. lactis</i> + <i>L. bulgaricus</i> + <i>Leuconostoc</i> obtained higher scores 93.17% and 94.33%, respectively.	964
1982	Rennet extract is prepared from abomasum of slaughtered calves	Renate extract has been prepared using 10% sodium chloride solution with 6.0% boric acid as preservative. The extract has found to coagulate milk effectively at 30.5 °C.	965
1995	Preparation of Austogram cheese	Citric acid @ 850 ml/5 kg whole milk at 73 °C has been used to produce Austogram cheese. Firm curd thus formed sliced by knife, settled for 30 minutes and then 3% salt is added in the finish product, allowed to dry at RT for 24 hours, and could be stored up to 30 days at 21 °C	966
2004	Rennet is not available in local market and lactic, citric & tartaric acids & sour whey have been approved as coagulants	These acids and sour whey are used as coagulants for making cheese. Lactic acid produced the best quality cheese and citric acid 1-2% is widely used with desirable results. Milk is coagulated by means of lactic acid produced by bacteria or by rennet or both. Cheese keeps longer than fresh milk and is easier to transport. Method of preparation of cheese is described.	967
2005	Physical, chemical and bacteriological evaluation of Dhaka cheese	Low, medium and high salted Dhaka cheese have been evaluated on physical, chemical and bacteriological methods. Presence of high level of microbes in all the samples which indicate unsanitary condition. However, the medium-salted Dhaka cheese has the highest acceptability.	968
2008	Quality of cheddar cheese	Effect of hot ripening on the quality of cheddar cheese has been reported	969
2010	Evaluation of physical and chemical qualities of mozzarella cheese	The physical and taste scores of Mozzarella cheese made from cow and buffalo milk reported similar. Cheese made of buffalo milk had higher fatt, protein, ash and total solids than cheese made of cow milk.	970
2015	Effect of salting & salt conc in Dhaka cheese	Combination of 2% (w/w) salt stuffing and bringing showed significantly better distribution of salt followed by only bringing	971
2017	To standardize the desire level of papaya latex on quality of cottage cheese	Five groups of cheese have been prepared with 0.28g rennet, 5, 6, 7, and 8 drops papaya latex (PL). Cheese prepared from buffalo milk with 6 drops of PL (papain) have reported highest acceptability for preparation of desired quality cheese. The procedure of cheese preparation with PL have described	972

### **Cheese making procedure of Austogram**

- Cheese is prepared by producing curd from milk by adding crude rennet extract.
- This is obtained from the fourth stomach (abomasum) of cows and goats.
- The abomasum obtained from slaughter houses is washed and dried with sodium chloride and is kept till it is used.
- Before cheese making, this is soaked in water for at least 12 hours. This is locally known as 'maoa.'
- The raw milk is set with maoa and the coagulation takes place within an hour.

- The curd is broken by hand or a bamboo knife and settled for a few minutes, then packed in a basket. The whey is pressed out by hand.
- For proper size and shape turning is made at certain intervals.
- When the curd is sufficiently dry after 24 hours, it is salted with sodium chloride.
- The salt is plugged into three centrally bored holes.
- The cheese is then ready for sale.

#### **Analysis of cheese**

- Five cheese samples of these manufacturers were collected and analyzed.
- These cheeses were found to contain 39.5% fat, 5.12% salt and 60.7% total solids.
- The TVC was 400,000,000 / g after incubating for 120 hours at 20 °C in plate count agar.
- The gram positive cocci constituted the predominant flora microorganisms

#### **Methods of collection of rennet**

- The abomasum of suckling slaughtered calves of different ages should be collected.
- The stomachs should be cleaned by rinsing in cold water and the adhering fats are needed to be removed mechanically.
- The mucous membrane of each stomach should be separated and cut into pieces of convenient size and then should be weighed in grams.
- The fresh cut pieces of each stomach should be added to 500 ml of 10% sodium chloride containing 6% boric acid as preservative and then macerated for 3 days in the refrigerator.
- After 3 days of maceration the samples should be filtered and the filtrates are collected and the keep in the refrigerator until the activity tests are made.
- The extraction should be repeated twice with the same sample of stomachs and filtrate should be collected after 3 days and 5 days respectively.
- All the successive collection of filtrate from each stomach should be pooled together and quantities obtained should be noted and store in the refrigerator.
- Six samples of rennet extracts obtained from different calves are tested first to find the desired concentration for suitable coagulation in milk.
- Each sample of rennet extract should be diluted with distilled water into 1:10, 1:20 and 1: 30 ratio.
- One ml portion of each dilution should be added to 10 ml portion of whole milk and then need to be incubated at 30.5 °C for half a minute and two minutes respectively in thermostatically controlled water bath.
- On the basis of rennet test for strength of rennet, the strongest rennet coagulates milk rapidly within one minute.
- Coagulation of milk in one minute is considered better for proper clotting of milk.

#### **Some observation**

- Milk samples which coagulated in 1 minute are considered to be the desirable strength for the coagulation of milk.
- If rennet extracts obtained from calves of early ages, i.e. 14 to 20 days or less are suitable for the quick clotting of milk.
- If the rennet extract is transferred from the sunlight to low temperature and keep there for a while, the activity of rennet extract might be regained.

- The cheese manufactured by using rennet extract prepared from the fourth stomach of calves of 14 to 25 days showed no flavor deteriorations but the cheese made from rennet extract of calves of 150 to 200 days gave a little bitter taste.
- Bitter taste in finished cheese indicates that the rennet extract obtained from the calves of 125 to 200 days, might contain more pepsin, good for the coagulation of milk.
- It appears that the quality of cheese depends on the nature of rennet extract used for preparation of cheese.

#### **Preparation of cheeses<sup>967</sup>**

- The cheeses are prepared by coagulating milk using lactic, citric and tartaric acid.
- Each 1.5 kg of milk is placed in three vats separately.
- The milk is heated to 85 °C and 2g coagulants per kg of milk are added.
- The milk stood for 40-45 minutes.
- When coagulation is completed the curd is cut into several pieces with a knife and left to settle for 25-30 minutes.
- The whey is separated by fine muslin and the resulting curd is put into a wooden box with addition of 1% salt. Then, it is kept in refrigerator for further study.

#### **Preparation of cheese<sup>963</sup>**

- Freshly drawn milk is supplied from BAUDF with acidity ranged from 0.16 to 0.18%
- The milk is then placed in two vats each containing 20 lb of milk for making two different blocks of cheese.
- The milk is heated by hot water supplied from a hot water tank.
- At 30-31 °C 'lactic starter' is added @ 4-5 oz for each 20 lb milk.
- The acidity is increased by 0.01-0.02% usually within 40-50 min.
- Hansen's commercial rennet is added for coagulation.
- The milk is coagulated within 40-45 minutes and it is cut with a knife or broken by hands into smaller particles.
- The salt is added @ 3 oz / 20 lb of milk in two methods.
- In one bucket salting is done by sprinkling as the curds are hooped in a basket.
- In another, salt is plugged through centrally bored holes after 24 hours of hooping.

#### **Preparation of cheese<sup>970</sup>**

- Rennet and starter culture are collected from Classic Dairy Foods, beg Housing, Khagdohar, Mymensingh
- The milk is heated at 80 °C for 30 minutes and then cooled for about 45 minutes to 38-40 °C and a culture of thermophilic bacteria (5%) is then added.
- After 30 minutes, calcium chloride (CaCl<sub>2</sub>) dissolved in water is slowly added at 0.5g/2.5 L of milk and after 15 minutes rennet dissolved in water is slowly added at 0.5 ml/2.5 L of milk.
- While adding CaCl<sub>2</sub> and rennet, milk is agitated by curd rake and ripened for about 40 to 50 minutes for curd formation.
- When curd formation is completed it is cut into cubes by curd cutter and the temperature is raised to 45 °C, while stirring gently.

- After 15 minutes the whey is removed from the curd using cheese cloth and put into a wooden cheese dice.
- The cheese is kept for 12 hours or one night in refrigerator and taken out and dipped into 25% salt solution for 30 to 40 minutes.
- The cheese is wiped with soft cloth and packed tightly with transparent polyethylene.
- Cheese thus prepared is defined as Mozzarella cheese and is stored in deep freeze.

### **Procedure of cheese preparation**

- 2.5 liter milk is boiled at 81 °C and after cooling at 40 °C 0.03% calcium chloride is added and allowed to stand for 10 minutes.
- Then bacterial culture [generally 1% starter culture (sour dahi)] is added to the milk sample.
- After addition of starter culture, the milk sample mixed thoroughly.
- Ripening is taken for one hour at 40 °C.
- Lactic acid bacteria are responsible for turning lactose into lactic acid, thereby reducing the pH of the solution. When the pH is lowered, the protein is more easily precipitated.
- This is the vital for the production of cheese curds.
- At that time the milk is allowed to ripen for one hour up to reaches appropriate pH level.
- After the addition of starter culture 5,6 7,8 drops papaya latex (papain) and 0.28g rennet is added for coagulation of milk.
- After collection of fresh papaya from the garden washed with alcohol and punched with syringe and latex is collected drop by drop.
- The papaya latex served to coagulate the milk protein and formed curds.
- Required quantity of papaya latex (papain) is added to the sample by thoroughly mixing and allowed to stand for 3-4 hours to complete coagulation.
- The coagulated curd is cutted into small pieces like ¼ to 5/8 inch cubes using stainless steel wire knife for removing whey water from the curd and gaining appropriate pH.
- The curd is cooked at 46 °C for 20 minutes with stirred constantly.
- When most of the whey is drained out from the coagulated curd it is collected.
- When all of the curd is milled about 1% (by weight) salt is added.
- Then the curd is hooped and pressed into a stainless steel dices to form cheese block by forcing pressure.
- After collection of cheese it is kept in refrigerator for further use.
- It may be concluded that cheese from buffalo milk with 6 drops papaya latex (papain) had highest acceptability for preparation of desired quality cheese.

### **Ice cream**

Ice cream is a frozen dairy food with mixture of milk, cream or butterfat, sugar and flavoring ingredients that has been frozen into a soft, creamy delight using special techniques. Hundreds of flavors have been devised, but most popular being vanilla, chocolate and strawberry.<sup>973</sup> Table 42 shows the research findings on ice cream in Bangladesh.

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Table 42. Composition, microbial contamination and quality of **ice-cream**

Year	Parameters	Research findings	References
1983	Bacteriological status between commercial & lab made ice-cream	The TBC and TCC of commercial ice-cream varied from 92000 to 252000 CFU/g and 32 to 71 CFU/g, in comparison to an average of 49000 CFU/ml and 4 CFU/ml in lab made ice-cream, respectively. Ice-cream produced in the lab possessed more hygienic status than those produced commercially.	974
1984	Stabilizer of Ice-cream	The ice-cream made of stabilizer sodium alginate alone having 0.25% conc. reported best in respect of flavor, body texture & melt-down properties	975
1986	Quality between commercial & lab made ice-cream	The TVC, TCC, acidity % and fat % of market ice-cream varied from 92000 to 252000 CFU/g, 31-75 CFU/g, 0.21 -0.26 % & 2.4-8.55% in comparison to 49000 CFU/g, 4 CFU/g, 0.16% and 12.0% in lab made ice-cream, respectively.	976
2000	Bacteriological status of market Ice-cream	TBC of Milk-vita, Igloo, Polar and Savoy ice-cream have been reported with an average of 3280, 3450, 15000 and 42460 CFU/ml respectively. TCC has been recorded in ice-cream of Polar (11.6 CFU/ml) and Savoy (28.0 CFU/ml) but not in Milk-vita and Igloo ice-cream.	977
2002	Sanitary quality of commercially produced ice cream	The average TBC (CFU/ml) of ice cream of Milk-vita (3280), Igloo (3450), Polar (15,000) and Savoy (42460) have been reported. Ice cream of Milk-vita and Polar reported negative for coliform and Staphylococcal count but other two ice cream reported positive.	978
2006	Evaluation of composition of ice-cream	The skim milk + 4% vegetable oil + 5% non-fat-dry milk have been reported to be produced the best quality ice-cream. The procedure of preparation is described.	979
2008	Evaluation of bacteriological quality of commercial ice-cream	The average TBC of Kwality, Igloo and Sub Zero ice cream have been reported to be $2 \times 10^3$ , $3 \times 10^3$ and $4 \times 10^3$ cfu/g, respectively. Total coliform count of these ice-cream have been reported as 12, 18 and 32 cfu/g respectively. It appears that the coliform bacteria exceeded standard limits, which can cause serious human health problems	980
2012	Bacteriological evaluation of commercial ice-cream	The presence of <i>Staphylococcus</i> spp. (96.0%), <i>Bacillus</i> spp. (50.0%), <i>Listeria</i> spp. (41.46%), <i>Micrococcus</i> spp. (12.50%), <i>E. coli</i> (8.33%) and <i>Klebsiella</i> (8.33%) in the ice-creams indicate the lack of good manufacturing practice in production of ice-cream which imposes great risk to the consumers	981
2015	Bacteriological evaluation of commercial ice-cream	The total bacterial count (TBC) of the five commercial band of ice-cream ranged from $4.9 \times 10^3$ to $7.9 \times 10^5$ cfu/ml. <i>Shigella</i> spp. and <i>Listeria monocytogenes</i> have been isolated from these ice-cream. Maintenance of appropriate hygienic condition during manufacturing and storage of ice-cream products are required.	982

### Procedure of ice-cream preparation

#### Method-A<sup>973</sup>

- $\frac{3}{4}$  cup white sugar, 1 cup heavy whipping cream,  $2\frac{1}{4}$  cups milk and 2 teaspoons vanilla extract
- Stir sugar, cream and milk into a saucepan over low heat until sugar is dissolved.

- Heat just until mix is hot and a small ring of foam appears around the edge
- Transfer cream mixture to a pourable container such as a large measuring cup. Stir in vanilla extract and chill mix thoroughly, at least 2 hours (overnight is best).
- Pour cold ice cream mix into an ice maker, turn on the machine and churn according to manufacturer’s directions, 20 to 25 minutes.
- When ice cream is softy frozen, serve immediately or place a piece of plastic wrap directly on the cream and place in freezer to ripen 2 to 3 hours.

Method-B<sup>979</sup>

- Whole milk or skim milk, sugar (14%) and ice cream powder (2%) were mixed in a saucepan and heated up to boiling along with continuous string.
- The saucepan is taken out from the heater and allowed to cool down to room temperature.
- The mix is kept in the refrigerator at 4 °C for 24 hours.
- The cool mix is subjected to over-running for 45 minutes.
- After over-running the sample is poured in small cups and was transferred into deep freeze at - 20 °C for hardening.

**Dahi (Yoghurt)**

Dahi is considered the oldest fermented milk product of Indian sub-continent and may be considered the western equivalent to yoghurt. Curd and dahi mean one and the same thing in the Indian sub-continent and both are made from milk and are fermented by adding healthy bacteria to the milk. Curd is prepared after curdling warm milk using some amount of curd or dahi. Dahi does not include milk coagulated by the addition of acids or milk enzymes. Traditionally, dahi is prepared by natural culturing of boiled and subsequently cooled milk resulting in variability in its quality due to undefined starter cultures and uncontrolled fermentation.<sup>983</sup> Yoghurt is a fermented milk product prepared by addition of both *Streptococcus thermophiles* and *Lactobacillus bulgaris* as the starter culture because of their symbiotic relationship.<sup>984</sup> The function of the starter cultures is to ferment lactose (milk) sugar to produce lactic acid. The increase in lactic acid decreases pH and causes the milk to clot or form the soft gel that is characteristic of yoghurt. The fermentation of lactose also produces the flavor compounds that are characteristic of yoghurt. Functional properties of traditional dahi could be enhanced either by modification of basic milk, exopolysaccharide producing starter cultures, introduction of probiotic cultures and inclusion of diverse food additives like fruit juices, herbs and spices. Table 43 shows the preparation and evaluation of dahi which are locally produced in Bangladesh.

Table 43. Preparation and evaluation of yoghurt marketed in Bangladesh			
Year	Research objectives	Summary of research results	References
1972	Bacteriological quality of dahi tested from five sweetmeat shop of Mymensingh town	These dahi has been reported to be contained wide varieties of bacteria with no uniformity. Higher proportion of lactobacilli has produced dahi which criticized for high acid taste and lacking desirable flavor. A ratio of two or more streptococci to one lactobacillus would give better results	985

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1974	Preservation of starter culture at RT in different buffer solutions	Harvested and washed cells of starter culture have been preserved at RT in phosphate buffer pH 7.0, citrate buffer pH 6.8 and phosphate buffer with 20% glycerol. Phosphate buffer has reported to preserve the cells better than other two buffers	986
1975	Effect of adding skim milk powder with whole milk for preparation of yoghurt	Dahi made with 10 and 15% skim milk powder with mixed whole milk of cows and buffaloes have been reported an attractive appearance and hard consistency. Dahi with 10% added solids showed most liked body and appearance. Procedure of yoghurt preparation has been described	987
1986	Comparison of starter cultures between lab culture and market culture for the preparation of dahi	Lab culture contained <i>Streptococcus lactis</i> and <i>Lactobacillus bulgaricus</i> while the market culture which have procured from sweetmeat shop contained mostly lactobacillus and some contaminants like yeast and molds. Dahi prepared with lab pure culture has been reported better than that with market culture	988
1992	Effects of milk sources on the quality of fresh dahi	Milk powder, whole milk and skim milk have been used for preparation of dahi and their evaluation on score. Out of 100 total score, dahi made from powder milk showed 77.25%, whole milk 82.25% and skim milk 75.0%. Dehydrated at 50 °C dahi made from whole milk secured highest score	989
2000	Evaluation of five different types of dahi prepared with cow and buffalo milk alone and combination	Chemical quality of buffalo's milk dahi has been reported superior to other dahi but organoleptic score has significantly higher in buffalo : cow milk (50 : 50) dahi. General acceptability of buffalo : cow (50 : 50) milk dahi has been reported higher than that of other dahi samples. Procedure of dahi preparation is described.	990
2001	Yogurt prepared by adding jack fruit juice with milk	Addition of jack fruit juice increased the total solids content but decreased the protein, fat and ash content. Yeast cell reported higher in jack fruit yogurt than plain yogurt and 5% jack fruit juice yogurt has been suggested	991
2002	Comparison between market dahi samples & lab made samples	Results suggested that adulterated milk must be avoided in yogurt preparation and also to follow strict hygienic condition in order to have good quality yogurt	992
2002	Comparison between covered and uncovered conditions of the dahi cups	Dahi prepared by using banana juice and one group covered with paper on the top of the cup and another group without covered. Both the groups have kept inside the refrigerator at 50 °C for 16 days. More water removed in uncovered than covered dahi cups. Cover on the dahi container is required when stored at refrigeration condition	993
2002	Preparation & evaluation of different types of fruits dahi	The overall score have been reported to be very high in date palm dahi (83.42%) and very low in mango dahi (73.42%). Even the fruit dahi has been reported to be superior than plain dahi.	994
2002	Use of seasonal fruit juice in dahi	The different seasonal fruits available in local markets have been used for the preparation of dahi	995

2004	Feasibility of using vegetable oil and powder milk with skim milk for dahi preparation	Six different types of dahi have been prepared from whole milk, skim milk and admixture of powder milk with different levels of vegetable oil. The addition of vegetable oil ( <b>soybean oil</b> ) @ 2-6% together with 5% non-fat dry milk (powder milk) have improved the quality of dahi. Method of dahi preparation has described	997
2004	Preparation & evaluation of single culture dahi prepared from whole milk with or without powder milk	Dahi prepared from whole milk with 5% powdered milk and 8.0% sugar scored the best for physical, chemical and microbiological qualities. Dahi prepared by using monoculture of <i>Lactobacillus acidophilus</i> has shown that easily be prepared in tropical environment	998
2005	Comparison of the dahi prepared from different species milk	Dahi prepared from cow milk has been reported superior than dahi prepared from buffalo or goat milk. Milk of all the three species of animals have shown mostly equal nutritive value	999
2005	Chemical and microbiological evaluation of traditional dahi	Highest TS content of Bogura dahi (38.24%) and lowest in Mymensingh dahi (29.82%) whereas highest fat (4.88%) and protein (4.74%) in Mymensingh dohi. Similar contents in Dhaka & Jamalpur dahi	1000
2006	Feasibility of using soya milk for the preparation of dahi	Results showed that 20% soya milk has been used for the preparation of dahi successfully which produced dahi nearly similar to the quality of buffalo milk	1001
2006	Microbial quality of yoghurt drinks	Microbial quality of fermented yoghurt drinks prepared from skim milk by adding different types of flavors and levels of sugar have been reported	1002
2007	Evaluate the shelf-life of normal and heat-treated dahi in RT and RFT	Shelf life of normal dahi has been reported to be good up to 2.3 days at RT (28.3 °C) and 7.3 days in RFT (5-6 °C) whereas up to 3.3 days and 38.3 days with heat-treated dahi, respectively.	1003
2007	Quality evaluation of market yoghurt	The yoghurt sold in the Chittagong metropolitan area in Bangladesh have been evaluated	1004
2008	Coconut milk added yoghurt	Preparation of yoghurt from cow milk adding of coconut milk has been reported	1005
2008	Evaluation of quality of dahi	The quality dahi prepared from different forms of commercial milk have been evaluated	1006
2009	To compare the market yoghurt with Lab made yoghurt	The Lab made (A) and market yoghurt collected from Kishoregonj (B), Gazipur (C), Bogura (D) and Dhaka (E, F) districts have been evaluated and quality of yoghurt A reported superior than others	1007
2010	Effects of different levels of sugar and mixed culture on qualitative characteristics of dahi	Sugar 8, 10, 12 and 14% and mixed culture 1,2,3 and 4% have been added in dahi, respectively. A combination of 10% sugar with 2% culture and 12% sugar with 3% culture have found appropriate for dahi making	1008
2010	Five types of dahi with starch & potato mash	Result showed that 2% commercial starch powder dahi has been produced successfully similar to plain dahi	1009
2010	Preparation and monitor Dahi for diabetic patients	Dahi with sugar, dahi with sac-sweet and dahi with sucrose have been prepared with acceptable quality for diabetic patients.	1010

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2011	Evaluation of the quality of commercial dahi of sweetmeat shops (Sylhet)	Dahi tested from the five major shops of Sylhet town showed that these dahi have not maintained the proper quality and contaminated with yeast and mold, however, the dahi of Fulkoli Brand found acceptable.	1011
2011	To evaluate qualitative characteristics of dahi prepared from non-fat-dry milk (NFD) with vegetable oil	Dahi prepared from skim milk powder by adding vegetable oil (40g soybean oil) and 200g of skim milk powder per liter (20% NFD + 4.0% vegetable oil + 5.0% gelatin) produced dahi similar to the quality of whole milk dahi.	1012
2011	To evaluate & compare the different market dahi	Commercial brands of dahi (Bogura, Bonoful, Arong, Muslim and Grameen soktee) have been evaluated as excellent to acceptable	1013
2012	Chemical and bacteriological quality evaluation of popular dahi of six distinct town	TBC (log cfu/g) and TCC (log cfu/g) have been found highest in dahi of Bogura (8.03 & 2.01) in comparison with Khulna (7.46 & 0.76), Barishal (5.76 & 1.20), Savar (6.45 & 0.76), Sylhet (7.13 & 0) and Comilla (6.97 & 0). Sugar and ash contents found very high but low fat content due to malpractices	1014
2012	Dahi has been prepared with 0, 5, 10 and 15% potato mash with storage	The addition of 5.0% potato mash in dahi has improved the storage quality that consumed up to 3 days at room temperature and 12 days at refrigerator temperature.	1015
2012	To prepare fruit yoghurt fortified with fruit juice of different fruits	The yoghurt fortified with 10% orange juice reported more acceptable than yoghurts prepared with strawberry and grape juice. Yoghurt with 5.0% fruit juice have also reported of acceptable in quality.	1016
2013	Preparation of dahi with mixed milk (whole cow milk + soy milk) and mango juice	Addition of 10% mango juice prepared a high quality low cost mango flavored soy milk dahi with high physical quality but somewhat deviation of chemical properties. The mango flavored soy based dahi found acceptable due to high price of milk. Procedure has described.	1017
2013	To assess the quality of yoghurt prepared from different forms of milk	Yoghurt has been prepared with whole milk, skim milk, powdered skim milk with added milk fat showed that the yoghurt from whole milk ranked the highest followed by others	1018
2013	To evaluate the quality of yoghurt made in the Lab and collected from local markets	Significant difference in smell and taste, color and texture, protein, acidity and pH value and microbiological status have been reported among different yoghurt samples. The Lab made yoghurt has been reported as the best in quality.	1019
2014	Feasibility of using date palm brown sugar as alternative to refined can sugar in sweet dahi	Four types of dahi containing 10%, 12% and 14% date palm brown sugar and 12% refined cane sugar have been prepared, of which dahi contained 12% date palm brown sugar reported best among the dahi. Procedure of preparation of date palm dahi has described.	1020
2014	Quality evaluation of dahi prepared with skim milk fortified with 5%, 10% & 15% mango juice	The addition of 10% mango juice with skim milk showed higher quality mango fruit flavored dahi with 0.07g/kg fat, 4.03g/kg protein, 0.92g/kg ash, total solids 32.16g/kg, pH 4.59, TVC 108.3 cfu log and coliform 8.0 (MPN g <sup>-1</sup> ). Preparation procedure of mango fruit flavored dahi has been described.	1021

2014	Feasibility of using coconut milk by replacing skim milk for dahi preparation	Reconstituted skimmed milk replaced by 0, 10, 20 and 30% coconut milk to produce dahi. The replacement of 10% and 20% skimmed milk with coconut milk produced better dahi which enrich the nutritive value and comparatively cheaper. Preparation procedure has described	1022
2014	Evaluation of brand market yoghurt	Physical, chemical and microbiological evaluation of brand dahi of Bogura district have been reported	1023
2015	Dahi prepared by partial replacement of buffalo milk with soy milk	Four types of dahi have been prepared with 100% buffalo milk (BF), 50% BM + 25% soy milk (SA), 50% BM + 50% SM and 25% BM + 75% SM. Dahi made by a mixture by a mixture of 25% SM + 75% BM produced better results.	1024
2015	Chemical and microbiological evaluation of market dahi of four different bands	Yoghurt available in the local market appeared that the nutritional level has not been maintained. Coliform contamination recorded in all the four bands of yoghurt at a ranged between 6.66 to 54.66 cfu/ml whereas only band yoghurt contained Salmonella contamination (2.0 cfu/ml).	1025
2015	To assess the microbiological quality of commercial yoghurt in Sylhet	Revealed that all the tested yoghurt samples exceeded the permissible limit ( $\geq 10^7$ cfug <sup>-1</sup> bacteria) for yoghurt. Of the chocolate, orange and fresh yoghurt, chocolate yoghurt has highly acceptable (8.69)	1026
2016	Feasibility of incorporating carrot juice in the yoghurt preparation with skim milk	Yoghurt prepared by incorporating 5% carrot juice reported best quality based on higher value of smell & taste, body & consistency, color and texture score.	1027
2016	Comparison of the quality of Netrokona market and lab made yoghurt	The quality of yoghurt samples collected from different sweetmeat shop of Netrokona district have been reported inferior qualities to yoghurt prepared in the lab based on physical, chemical and microbiological tests	1028
2016	Use of sodium alginate as stabilizer to improve the structural quality of sweet yoghurt	Yoghurt has been prepared with adding 0, 0.4%, 0.6%, 0.8% and 1.0% sodium alginate and reported that 0.6% produced effects as stabilizer to improve structural quality of yoghurt. It also enhanced the total solids, ash and protein content of yoghurt.	1029
2016	Quality assessment of yoghurt based on milk fat percentage	Yoghurt has been prepared with four different percentage of milk fat including 3.5%, 4.0%, 4.5% and 5.0%, of which yoghurt of 4.5% milk fat reported highest quality based on physical, chemical and microbiological tests	1030
2016	Evaluation of lossi by mixing dahi with 15,20, 25 and 30% water and 20% sugar	Result showed that the highest overall score has been reported in 20% added water lassi sample and lowest with 30% added water samples. Best lassi has been suggested through reconstituted milk dahi with 20% water along with 20% sugar	1031
2016	Partial replacement of skim milk with coconut milk in dahi preparation	Results showed that 5.0% replacement of skim milk with coconut milk scored highest and 10.0% replacement reported within acceptable range for manufacturing yoghurt	1032
2016	Partial replacement of skim milk with coconut milk in dahi preparation	Dahi prepared by replacement of 5.0 to 10.0% skim milk with coconut milk resulted better organoleptic qualities and chemical and microbiological parameters	1033

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2016	To evaluate the qualities of yoghurt collected from different sources	The evaluation of physical, chemical and microbiological qualities of yoghurt collected from Bogura and Mymensingh districts showed that the Maharam Ali yoghurt and BAUDF yoghurt reported superior	1034
2017	Evaluation of yoghurt prepared from cow's and buffalo's skim milk with mango juice	Attractive color and pleasant mango flavor yoghurt has been prepared with cow skim milk and buffalo skim milk with addition of 10% mango juice. TBC has been reported higher in 10% mango juice yoghurt but it produced better yoghurt in terms of organoleptic and chemical qualities	1035
2017	Comparison of mineral levels among powder milk, raw milk, ice-cream and yoghurt	Major minerals (Na, K, Ca, Mg & P) have been reported higher in powder milk, some found lower (Na, K & Ca) in raw milk and lowest levels of Mg and P in ice cream buy yoghurt and ice-cream contained intermediate levels of minerals	1036
2017	Compare the quality of commercial yoghurt of sweetmeat shop	Yoghurt of Bogura district has been reported best followed by Mymensingh and Tangail based on physical and microbiological quality	1037
2018	Investigation of microbiological quality of yoghurt collected from 10 districts	The level of TBC ( $1.72 \times 10^7$ to $3.64 \times 10^8$ ), TCC ( $1.02 \times 10^2$ to $4.51 \times 10^2$ ), total yeast and mold ( $2.0 \times 10^2$ to $9.4 \times 10^3$ ) counts in the yoghurt have been reported due to excessive contamination	1038
2018	Incorporation of carrot juice in dahi preparation	Results showed that the using of 15% carrot juice with whole milk has produced high quality fruit flavored dahi.	1039
2018	To develop lassi from sour dahi using different levels of sugar and 15% water	Results showed that good quality and nutritionally enriched lassi with more acceptability has been prepared from sour dahi using 15.0% sugar along with 15.0% water	1040

### Procedure of dahi preparation<sup>990</sup>

- Buffalo and cow milk are mixed and boiled for 5 to 10 minutes in order to destroy the viable organisms that present in milk and reduced up to 10-15% of volume of milk.
- Sugar is then added to the milk @ 125 g / l of milk.
- The boiled milk is then cooled to body temperature (36.4 °C) and inoculated with desirable proportion (2-3%) of starter culture which can be used local market dahi.
- Culture is mixed thoroughly and after mixing it is sampled in plastic cups and keeps in the incubator having the temp (35-36 °C) until the complete coagulation (8 to 12 hours).
- After complete coagulation the dahi samples are stored at refrigerator until further use.

### Method of preparation of fruit dahi<sup>994</sup>

- Whole milk is heated to boiling for about 20-30 minutes, non-fat milk powder is mixed with the whole milk in desired proportions (3%) before heating.
- The milk is stirred with spoon.
- Sugar is added to the milk @ 8.0% based on total amount of milk.
- After completion of heating milk is divided into five equal parts.
- Four different types of fruit juice namely mango, date palm, banana and apple juice is added to four cups except control (plain dahi).

- Fruit juice is added @ 10% based on total milk in the cups.
- The cups are incubated with culture.
- Heated milk is cooled to about 40 °C and inoculated with desirable proportion of cultures (2%).
- The samples are incubated at 37 °C until the complete coagulation of fruit's milk mixture.
- After 8-12 hours the complete coagulated fruit-milk mixture called fruit dahi are stored at refrigeration temperature.

#### **Preparation of banana juice and different types of dahi<sup>996</sup>**

- Mature ripe banana skin should be separated with the help of clean hand, the seed and black spotted are removed from banana fruit pulp.
- Then the banana pulp is blended and after completion of blending, the juice is filtered using clean cloth and then it is stored in the refrigerator until use.
- Whole milk is boiled in a pan for about 30-40 minutes to reduce 20-25% of its original volume.
  - Sugar is added to the milk @ 10% during boiling.
- During heating milk is stirred thoroughly with the help of a stirrer.
- After desired heating, milk pan is taken out from the heater and allowed to cool.
- Banana juice is taken out from the refrigerator and kept in the room temperature for thawing.
- When the temperature of milk became about 40 °C then the milk is divided into four equal portions.
- Banana juice is then added into each portion of milk as: A: 10%, B: 20% and C : 30% and D: Plain (control). Different level of banana juice could be used successfully to prepare fruit dahi but also makes the product cheaper in comparison with plain (control) dahi.

#### **Preparation of dahi<sup>997</sup>**

- Whole milk collected for the preparation of dahi is heated to boil consistently until it reduced to 20-25% of the volume of milk.
- At the boiling of milk, sugar is added @ 8% of the total volume of milk.
- During heating, milk is stirred thoroughly with the help of stirrer,
- After desired heating, milk pan is taken out from the heater and allowed to cool down to near 42 °C and inoculated with 2% starter culture.
- After inoculation, warm milk of 42 °C is poured into several clean plastic cups that are boiled previously for maintaining their hygienic quality and kept undisturbed at an incubation temperature of 37 °C until coagulation.
- After complete coagulation (3.5-4 hours), the dahi samples are taken out of the incubator and stored in a refrigerator at about 5 °C for analytical purpose.
- All dahi used in this trial are prepared following the above way.
- Powdered milk is added with the skim milk before heating of milk.
- Similarly, vegetable oil i.e. soybean oil is mixed to the skim milk during heating of skim milk. Before adding, soybean oil is heated for neutralizing its odd flavor.

#### **Methods of preparation of mango juice-soy milk dahi<sup>1017</sup>**

##### **Soy milk from soybean powder**

- 1.0 kg whole soybean seed free from immature field damage and black spot are grinded in a soy flour mill.

- 125g powder is dissolved with 1 liter of water by stirring.
- The soy milk is strained through a fine cloth to separate the residue.
- Soy milk is then boiled at 100 °C for 10-15 minutes with constant stirring.

#### **Preparation of mango juice**

- The mango fruit is washed by distilled water, skin is separated, seeds are removed and the fruit pulp is blended.
- After blending the juice is filtered by clean cloth and stored at refrigeration temperature (4 °C) until preparation of dahi.

#### **Procedure of preparation of date palm brown sugar added dahi<sup>1020</sup>**

- 2.5 liter of whole cow milk is boiled in an open pan called karahi for about 25 minutes in order to reduce the volume by 20%.
- The milk is then divided into 4 equal portions, 0.5 liter each.
- Date palm brown sugar is weighed at different levels 10%, 12% and 14% (weight/volume) of milk i.e. 50g (A), 60g (B), 70g (C) for each of 0.5 liter portion of milk.
- A standard 12% (60g for D) cane sugar as control.
- Date palm brown and cane sugar are added to each portion of hot > 90 °C milk and mixed well with a stirrer.
- The portions of milk are then cooled to 40 °C and 2% mixed starter culture is added to each portion.
- The portions are transferred into 100 ml cups and are incubated at 37 °C in an incubator for 5-6 hours.
- After coagulation, all the samples are put in a refrigerator at about 4 °C until tested.

#### **Procedure of preparation of mango flavored dahi<sup>1021</sup>**

- The collected whole milk is skimmed by an electric cream separator.
- Mango, sugar and starter culture are collected from local market.
- Ripened mangoes (*Mangifera indica*) are washed with clean water and skin is separated with the help of knife aseptically.
- The seeds are removed and mango pulps are blended.
- After blending, the juice was filtered with clean cloth (hot water washed).
- These kept in plastic containers and stored at freezing temperature (-20 °C) until preparation of dahi.
- Skim milk is heated to reduce about ¼ the of its original volume and sugar is added @12% during boiling. During heating, milk is stirred continuously with the help of a stirrer.
- After desired heating, milk pan is taken out from the heater and allowed to cool.
- When the temperature is about 40 °C, then milk is divided into four equal portions namely A, B, C and D and different types of dahi is prepared from each portion.
- Sample A served as control with mango juice and 5, 10, and 15% mango juice is added in group B, C and D respectively.
- Milk is inoculated with 2% starter culture and then distributed into plastic cups.
- The samples are incubated at 42 °C until the complete coagulation of dahi (7-8 hours).
- The dahi samples are stored at about 4 °C at refrigerator until judging.

### **Preparation of coconut milk dahi**<sup>1022</sup>

- The edible portion (cellular endosperm) of coconut is shredded carefully to avoid the waste material.
- Two cups of warm water (250 ml) for every cup of coconut are used to prepare coconut milk.
- The coconut and water are blended with high pressure until the mixture is as smooth as possible.
- When the blending is completed then the coconut milk is filtered by a clean muslin cloth (hot water washed) and kept it in a beaker.
- When skimmed milk powder is dissolved with water then it may be defined as reconstituted skim milk.
- Skimmed milk powder is added @ 9g/100 ml (w/v) of warm water to prepare reconstituted skim milk.

### **Research on beef cattle production**

There are more than 250 beef cattle breeds in the world and 60% of them are found in the USA.<sup>1041</sup> Currently, beef cattle production business are as popular as dairy production business. Some breeds have been around for centuries, while other have been developed in the last couple of decades by mixing older breeds like American Brahman.<sup>1042</sup> The beef cattle breeds of greatest prominence today originated in Britain (Herefords, Angus, beef Shorthorns and Galloways), USA (Black Angus, Beef Master & others), India (Brahman), France (Charolais, Limousin, Normandy), Switzerland (Simmental), South Africa (Afrikaner) and other countries.<sup>1042</sup> There is no any recognized beef breeds in Bangladesh, however, the male uncastrated native and cross-breed cattle are mainly used as a beef cattle.<sup>435,1043</sup> Recently, American Brahman semen has been imported to develop beef cattle in Bangladesh. The American Brahman is a result of 266 and 22 females imported from India to USA between 1854 and 1926. Since then breed has been selectively bred for meat production, making it the ideal breed for meat production.<sup>13</sup> In comparison to other breeds the American Brahman is able to utilize low quality feed, withstand a wide range of temperatures and consistently maintain a higher feed to weight ratio than most other contemporaries. Overall this makes the breed ideal for meat production in Bangladesh when crossbred with local cattle.<sup>1044-1046</sup>

Native and crossbred uncastrated cattle of two to three years of age are mostly preferred by the butchers for their business whereas rearing of cattle are mainly based on rice straw with inadequate capital, training, feed stuff and fodder crops and marketing facilities.<sup>1047</sup> Recently Brahman beef cattle breed has introduced in research in Bangladesh and it has observed that 50% Brahman cross calves well performed live weight of 229.62kg at 12 months of age in comparison with 25% crosses with local cattle.<sup>1044</sup> The hearth girth (HG) around the chest and in combination of HG and body length (BL) can be used efficiently to predict live body weight in Brahman crossbred cattle.<sup>1048</sup>

The per capita intake of meat is only 8.6 kg in humans Bangladesh against 42.1 kg for world and 32.2 kg of developing countries. Therefore, there is a need to develop market beef cattle of average >150 kg carcass weight by 24 months with an average FCR of < 6.5 under the farm feeding and management condition. An experiment has been conducted with imported frozen semen of beef breeds of Brahman, Simmental, Charolais and Limousin in native breeding cows,

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of which Charolais × Local cows cross progeny had highest birth weight (27.5kg), followed by Brahman cross (24.1kg), Simmental cross (21.9kg), Limousin cross (19.8kg) and lowest in native calves (18.4kg). Among the five genotypes, cross-bred Simmental has performed as the best in terms of growth (297.3kg) performance up to 12 months of age.<sup>1049</sup>

Table 44 shows the research findings on beef cattle production and marketing.

Table 42. Research findings on beef cattle production and marketing			
Year	Main objectives	Major findings	References
2003	Beef cattle breeding	Genetic trends in the development of crossbreeding system in beef breeding has been reported.	1050
2004	Genotype × environment Interaction in beef bulls	There is a need for environmental-specific genetic evaluation and selection of beef bulls for commercial beef production	1051
2007	Cattle fattening practices	About 56.7% of the farmers used cattle of 2-3 years of age and 36.7% used 1-2 years age for fattening period of 3 to 6 months (60%) and 7-12 months (30%), respectively.	1052
2009	To assess the problems of beef cattle rearing and marketing	Cattle of 2-3 years are preferred age for slaughter and beef price is usually fluctuating. Rice straw is main feed but scarcity of feed and fodder crops, training, pasture land and marketing.	1047
2000	To assess the agribusiness of beef and beef products	Agribusiness of cattle, beef and beef products have been reported to be profitable and diversified uses of beef have been suggested.	1053
2015	To assess the status of beef cattle production	Cattle feed are mainly based on natural grasses and rice straw. Feed is the major challenge for farmers to rear beef cattle.	1054
2015	To predict the live weight of Brahman cross-bred cattle by using linear body measurements	The morphometric characterization of Brahman crossbred cattle and prediction equations based on heart girth around the chest (HG) or in combination of HG and body length (BL) have been reported to predict live weight of Brahman crossbred cattle.	1048
2015	Effect of conc. : roughage on growth of Brahma cross calves	Effect of concentrate to roughage ratio on cost effective growth performance of Brahman crossbred calves have been reported	1055
2016	To compare the live weight between 50% and 25% Brahman cross calves	The birth weight (21.40kg) and 12-month weight (229.62kg) of 50% Brahman cross calves has reported to be significantly higher than 25% Brahman cross calves.	1044
2016	To predict live weight of Brahman × Local crossbred cattle using linear body measurements	The prediction equations based on heart girth or in combination of heart girth and body length have been suggested to be used efficiently to predict live weight of Brahman crossbred cattle in rural areas	87
2016	Effects of genotype × environment interaction on growth of Brahman cross	Significant interaction between sire × environment on growth traits of Brahman cross bulls have been reported. Breeding bull selection and use should be made on environmental basis.	1056

2017	To compare the live weight of different crossbred beef calves at birth and at 12 months of age	The birth and 12-m age live weight have been reported with Charolais cross (27.5 & 279.9 kg), Brahman (24.1kg & -), Simmental (21.9 & 297.3 kg), Limousin (19.8kg & 270.2kg) and Local (18.4kg & 194.7kg).	1049
2020	To evaluate the effect of sire and environment on growth performance of grade-2 Brahman calves	The sire and environment have reported to have significant effect on above growth traits at different ages of Brahman progeny which indicates that best sires in best environment can produce superior progeny.	1045
2020	Factors related to growth performance of Brahman graded calves	Improved feeding had positive impact on growth performance of Brahman growing bull calves. Growth performance had positively strong phenotypic correlation different growth traits and factors	1046

The higher birth weight, yearly weight and average daily gain of Brahman crossbred calves have been reported than that of indigenous and other crossbred calves.<sup>564</sup> It appears that these selected graded Brahman breeding bulls may generate a good opportunity to improve local cattle for beef purposes.

### Care of the calf at birth

When calving time approaches, the cow should be watched closely for any complications. The newborn calf should begin to breathe shortly after the umbilical cord detached from dam. Mucus around the nostrils should be removed. Do not pound on the calf's chest or lift it by the rear legs since this can do more harm than good. Shortly after birth, the navel cord should be dipped with a 7% tincture of iodine solution. The cow should be allowed to lick the calf after delivery. In cold weather or if the cow does not lick the calf, the calf should be dried with clean cloths. This practice not only dries the calf but stimulates the calf's blood circulation. Generally dairy calves are removed from their dam shortly after the dam has licked the calf clean, usually with one hour (<http://www.ca.uky.edu>).

### Birth weight and growth of calves

Growth is defined as the mass increase in animal live weight and divided into two periods as pre-natal and post-natal growth. Both the pre-and post-natal growth are in equally significant but the breeders generally deal with post-natal growth of animals. Birth weight is an early and easy indicator of pre-natal growth, which is commonly used as an early selection criteria in cattle breeding. **Table 45** shows the analyzed mean values of birth weight of calves reported in different breeds and varieties of cattle.

The birth weight of calves is of critical importance to the dairy and beef cattle industry. Calves that are too small at birth may lack vigor, tolerance to cold-stress, resistance to pathogens or the ability to overcome parturition stresses during adaptation to extra-uterine life. Calves that are too large at birth may cause varying degrees dystocia, leading to increased birth asphyxia, metabolic and respiratory acidosis, depressed immunoglobulin in absorption and increased susceptibility to diseases.<sup>1061</sup>

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Table 45. Analyzed mean values on the influence of breeds, gender and seasons on birth weight of calves									
SN Breeds	Management	Gender (BW kg/calf)		Overall mean	Seasons (BW kg / calf)			Overall mean	Ref. No.
		Male	Female		Summer	Rainy	Winter		
01. HF	Farm (F)	-	-	29.14 (92)	-	-	-	-	739, 1057
02. Sahiwal	Farm	-	-	20.52 (94)	-	-	-	-	739,1057
03. AFS	Farm	-	-	29.1 (86)	-	-	-	-	739
04. BC	SH	-	-	19.79 (624)	-	-	-	-	1044
05. Cross	F & SH	-	-	22.52 (598)	-	-	-	-	1057
06. RCC	F & SH	15.77 (232)	13.76 (208)	15.25 (1101)	14.34 (96)	13.98 (64)	13.98 (87)	14.10 (247)	A =
07. HF × L	F & SH	30.43 (79)	28.31 (65)	21.96 (910)	-	-	-	-	B =
08. SL×HF	SH	-	-	25.20 (153)	-	-	-	-	C =
09. HF×PV	SH	-	-	24.92 (361)	-	-	-	-	492
10. AFS×PV	F & SH	-	-	29.78 (515)	-	-	-	-	492
11. J × L	F & SH	-	-	17.39	-	-	-	-	D =
12. SL×L	F & SH	19.58 (20)	14.11 (17)	19.17 (348)	-	-	-	-	E =
13. SL× PV	SH	-	-	23.96 (659)	-	-	-	-	492
14. RS × PV	SH	18.34 (11)	17.73 (5)	18.04 (16)	-	-	-	-	735
15. SD x L	F & SM	18.38 (39)	17.55 (25)	17.25 (164)	-	-	-	-	F =
16. Pabna V	F & SH	20.61 (5)	19.76 (11)	21.49 (826)	-	-	-	-	G =
17. Local	SH	-	-	16.91 (399)	-	-	-	-	H =
18. Dhaka V	SH	32.98 (9)	29.2 (5)	31.09 (14)	-	-	-	-	735
19. MV	SH	-	-	14.83 (6)	-	-	-	-	58
20. NBGC	SH	-	-	18.35 (135)	-	-	-	-	58
21. DDC	SH	21.71 (14)	22.42 (12)	22.07 (26)	-	-	-	-	12
22. HF F2/ F3	Farm	-	-	25.72 (1476)	-	-	-	-	492,739

A = 42,43,58,635,732,735,756-758,777-779,782,783,967,1058

B = 635,739,745,747,754,756-758,761,766,1059,1060

C = 739,757,758,770

D = 745,747,754,756,757,758

? = Not mentioned in the article

SH = Smallholder

MV = Munshiganj variety

RS = Red Sindhi

AFS = Australian-Friesian-Sahiwal

RCC= Red Chittagong cattle

NBG = North Bengal Grey cattle

- = Data not available

E = 735,745,747,756-758,761,770

F = 735,747,756,761

G = 492, 735,785

H = 32,635,739,754,757,758,761,766,778

BC = Brahman cross

() = No. of observation

DDC = Dinajpur Dwarf cattle

Male calves, on average tend to be larger and higher birth weight than female calves (Table 45) because bovine males are larger than females and because male calves are often carried a few days longer than female calves of similar genetics, if a cow goes past her due date, she is likely to have a bull calves. If she calves a few days earlier, the calf is often a female calf.<sup>1062</sup> However, the birth weight can be affected by changing the rate of fetal growth or by changing length of gestation. Some breeds and family lines within breeds tend to have gestation lengths slightly shorter or longer than the average 283 days. Low birth weight cattle often have shorter-than-average gestation, and high birth weight cattle tend to have longer than average gestation. The fetus is growing fastest in the final stages, so several more days' gestation creates a larger calf. Study showed that each extra day of gestation amount to at least one pound more in the size or weight of the calf.<sup>1062</sup>

Environmental factors affecting growth rate include nutrition of the dam and environmental temperature. Overfeeding cows in late gestation increases risk for dystocia because of increased calf size and fat accumulation in the birth canal. Underfeeding to reduce birth weight is counter

productive, however, because of increased weakness and metabolic disease in underfed cows. The cow has poorer colostrum and won't pass adequate immunity to the newborn calf and this weak calf that is slower to get up, slower to suckle, and when it finally does suckle, it gets inadequate colostrum. No significant influence of season on birth weight of calves has been observed with these limited reports (Table 45). Calves born during rainy season reported approximately 10% heavier at birth than those born during the dry season elsewhere. It appears that the breed, gender and season of calving interaction have significant influence on birth weight of calves.

The RCC is a valuable indigenous cattle genetic resource of Bangladesh with many attributes better than other available indigenous types and varieties.<sup>46</sup> Table 45 shows that highest number of research reports (>16) on birth weight of RCC calves in comparison to other genotypes have been published from Bangladesh. The moderately high heritability of growth of RCC suggests that RCC selected for growth up to 24 months of age would show a quick response.<sup>1058</sup> An increasing trend in body weight from birth to 30 months of age with highest body weight gained at 30 months of age and then afterwards showed a gradual declining trend but no difference effects of management system (farm & field) on growth performance.<sup>46</sup> Although body weight and growth of RCC calves are very slow compared to crossbreds but comparatively higher other native cattle.<sup>1063</sup>

### **Calf management**

Heifers are the future of the dairy herd and deserve to have the best management that incorporates all the latest research and management advice. Raising heifer calves is the second largest annual expense, approximately 20% of a dairy business's production cost after feed. Heifers produce no income until they reach first lactation and no benefit until the second lactation. In the return, they will reply the investment through higher milk production and a longer productive life.<sup>1064</sup> Management of calves should be a good start with the first step in producing healthy, well grown replacement animals that are ready to enter the milking herd at 22 to 24 months of age. Starting calves off well is essential to minimizing death loss and improving health outcomes. Even when a calf survives a disease, negative economic impacts may occur, and it may never reach her full genetic potential.<sup>1065</sup> Calves treated with antibiotics have been shown to produce less milk in their first lactation than calves that receive no treatment with antibiotic.<sup>1065</sup> This suggests to encourage farmers to look more to disease prevention than treatment of heifer calves. There are three targets to raise the desired number of healthy, fertile and productive heifers which include: (a) Keeping calf morbidity and mortality to a low level, (b) Maintaining good calf growth and (c) Maintaining good calf health. The goal of calf nutrition is to promote healthy, efficient and rapid growth through milk and to enhance rumen growth and function by initiating calf starter intake.

### **Colostrum management**

Newborn calves have no innate immunity with immature immune system and depends on colostrum from its dam to initially acquire immunity through absorption of antibodies (IgG) which takes more than six months to fully mature immune system. The milk from the first milking following delivery is called true colostrum. After the first milking and for the next two and a half days, the cow's milk is called transition milk. True colostrum contains twice as much

dry matter and total solids, 2-3 times as many minerals and five times as much protein as whole milk (Table 46).<sup>1066</sup> Colostrum also contains various hormones and growth factors that are necessary for growth and development of the digestive tract. Colostrum is lower in lactose, thus decreasing the incidence of diarrhea.

SN Constituents (%)	Milking after calving				SN Constituents (%)	Milking after calving			
	Colostrum 1 <sup>st</sup>	Transition milk 2 <sup>nd</sup>	3 <sup>rd</sup>	Whole milk		Colostrum 1 <sup>st</sup>	Transition milk 2 <sup>nd</sup>	3 <sup>rd</sup>	Whole milk
1. Total solids	23.9	17.9	14.1	12.9	2. Fat	06.7	05.4	03.9	04.0
3. Protein	14.0	08.4	05.1	03.1	4. Lactose	02.7	03.9	04.4	05.0
5. Minerals	01.1	01.0	00.8	00.7	6. Calcium	00.26	00.15	00.15	00.13
7. IgG (mg/ml)	32.0	25.0	15.0	00.6	8. Vita-A (µg/dl)	295.0	190.0	113.0	34.0

Colostrum of the right quality and quantity given to the newborn calf at the right time which is the cornerstone of success for calf survival in any herd. It contains important nutrients like vitamins, minerals, energy and proteins, besides antibodies (IgG) and many other important substances. Colostrum is also called maternal derived antibodies (MDA) which are essential to protect the newborn for at least the first 2 to 4 months of life. There are five golden rules of colostrum feeding which include (a) Quickness (< 2 hours), (b) Quantity (10-15% BW), (c) Quality (> 50g IgG/L), (d) Frequency (multiple) and (e) Cleanliness.<sup>1067</sup>

**(a) Quick feeding of colostrum**

The calf should get colostrum as quickly as possible after birth, because the ability of the intestine to absorb colostral Ab (IgG) into the blood is most efficient during the first 4-6 hours of life. At about 12 hours after birth the absorption of IgG is reduced by 50% and after 24 hours the calf can hardly absorb any IgG at all. Milk the cows as soon as possible after calving to assure adequate delivery of abs to the calf. If the cow is milked in late after delivery for the first time, abs content of colostrum will decrease by dilution.

**(b) Quantity of colostrum**

Colostrum is the key to calf survival and newborn calves must receive at least 3.0 to 4.0 liters (10-15% of the body weight) of colostrum within 2 hours of birth and 2-3 liters within six hours after birth depending on the live weight of calves. Protein, fat and sugars from colostrum help to increase the calf's metabolism and heat production. Moreover, colostrum intake facilitates the first feces (meconium). The colostral abs (IgG) are absorbed within 24 hours in bovine which help to protect the calf against infection for 3 to 4 weeks. The calf requires first 4 to 6 weeks times to develop own protective mechanism.

**(c) Quality of colostrum**

Only feed colostrum with at least 50g/liter of antibody (IgG) by testing with a Brix refractometer or colostrometer. Colostrum with < 50g/L IgG will not provide an adequate protection to the newborn calf. Colostrum should be given to the calf directly after milking the cow for the first

time. Fresh excess colostrum can be stored within one hour of collection in the refrigerator for up to 24 hours and in the freezer (-20 °C) for one year. Frozen colostrum should be thawed slowly in a hot water bath at a temperature of 50 °C. Colostrum should not be fed to calf from dam affected with mastitis, Johne's disease and Bovine virus diarrhea and other diseases.

**(d) Frequency of colostrum feeding**

The calf should receive multiple colostrum feedings by bottle during the first day of life. Teat feeding with a nipple bottle is best. Use a stomach tube if a calf is unable to bottle or is too weak to consume the full amount of colostrum

**(e) Cleanliness**

Strict hygiene standards for cleaning and sanitation should be maintained when milking a fresh cow. The udder as well as the milkers should be thoroughly cleaned. Unhygienically collected colostrum can be contaminated and feeding of such colostrum may cause gastro-intestinal infection of newborn calf that may interfere absorption of colostral IgG in the intestine and even may cause enteritis. There is a need to test colostrum for bacteriological count to identify if improvements of colostrum hygiene are needed during collection and storage. Blood IgG antibody levels of calves should be checked to detect that the colostrum has been successfully absorbed to the calf.

Growth rate especially measure live weight at birth and then regularly should be monitored. Colostrum contains growth factors, hormones and other biologically active factors which positively impact the development of the digestive tract. Calves which do not intake and absorb adequate colostrum (IgG antibodies) have lower weight gain, increased risk for disease and death and decreased milk production during their first lactation.

**Feeding of milk and milk replacer**

The first 3 to 4 months of calf's life is a critical period and the feeding program at this time is important for rapid growth and development of baby calves and reducing death losses. Feeding of whole milk is expensive and milk replacers have been developed to reduce the amount of whole milk used raising calves. Traditionally, whole milk should be fed to calves at 10% of body weight that may be translated into feeding two liters of milk twice daily. Feeding of this two liter of milk does not provide sufficient energy to growing calves. Accordingly, feeding of 15% of calf body weight in whole milk or suitable milk replacer has been suggested. It is a legal requirement to feed calves under 28 days old at least two liquid milk feeds per day. The feeding of correct energy and volume of milk include improved health, growth rates, feed efficiency and lifetime milk performance. The waste milk including antibiotic treated milk, mastitic or high somatic cell count should not be fed to calves. Feeding of these types of waste milk can increase the risk of disease transmission and antibiotic resistance in the calf. The energy requirement of calves less than 3 weeks of age should be met through milk feeding and over 3 weeks of age through a combination of milk, calf starter and forage feeding. Calf should be fed milk at a temperature of 37-39 °C to ensure coagulation in the abomasum. To achieve this, milk should be heated to 40 °C which can also be applied to colostrum and transition milk. Pasteurized milk can also be fed to calf with no antibiotic residues.

### **Calf milk replacers (CMR)**

A good quality CMR should be similar in chemical composition to whole milk. A good quality CMR will contain only milk derived protein (MDP) sources. It should contain the nutrients that calves can digest and in the right proportions. The CMR is generally formulated from by-products of dairy processing, together with animal fats plus added vitamins and minerals. Whole milk powder consists of mainly of 36-40% lactose, 30-40% fat and 28-32% milk protein of DM basis. The by-product of butter making is skim milk which consists mainly of lactose and all the milk proteins but it has only half the energy value of whole milk. Whey, the by-product of cheese making, consists only of lactose, albumin and globulin and is even lower in nutritive value.

The CMR should contain 20 to 27% crude protein and 16 to 20% fat to achieve optimum growth rate (> 900g/day) in early life. Protein sources can be either milk or plant or vegetable proteins. However, the MDP are important for the first 2 to 3 weeks of calf's life because calves aged up to 3 weeks can only digest MDP efficiently. The MDP sources include skim milk powder, whey powder and butter milk powder. Fiber is an indicator of protein quality and protein with less than 0.15% fiber contain milk or egg, whereas fiber levels over 0.20% indicate inclusion of plant proteins. All milk protein include dried whey protein concentrate, dried whey, dried whey product, skim milk, casein and sodium or calcium caseniate whereas alternative plant protein include soy protein isolate, protein modified soy flour, soy protein concentrate, soy flour, animal plasma, wheat gluten and pea protein. Digestibility and subsequent calf growth and feed efficiency are lower with vegetable proteins than with MDP. Soy protein products can contain a variety of anti-nutritional factors that further decrease the digestibility of growing calves.

The CMR should contain 10 to 25% crude fat with 18-20% fat content ideal. Review of research reports show that there is no benefit to feeding CMR with higher than 18% fat content. Calves less than two weeks old cannot digest non-milk fats as well as milk fats. Higher fat CMR may suppress concentrate intake, so may not be suited to systems requiring early weaning. Fat sources should be highly digestible Protein sources are generally classified as either all milk or a portion coming from alternative proteins and preserved with an anti-oxidant. Fats commonly used include tallow, lard, palm and coconut oil. Tallow- a by-product of abattoir, is the most common fat to include because vegetable oils which contain high level of polyunsaturated fats, can cause scouring in calves. Tallow is preferred because it has a similar fatty acid composition to milk fat and is comparatively cheap. Coconut and palm oil have a similar digestibility to milk fat (about 96%).

Ash, vitamins and minerals in CMR should be added as per nutritional requirement and the ash content should not be higher than 8.0% with target ash content of 6.5 to 7.5%. The mineral and vitamins requirement of calves include as calcium 1.0%, phosphorus 0.7%, vitamin A 9,000 iu/kg, vitamin D<sub>3</sub> 600 iu/kg and vitamin E 50 iu/kg.

Calves may be started on a CMR when 2 to 4 days old, but the shift gradually from raw milk to CMR. Abrupt changes will increase the likelihood of nutritional scours and stress. Commercial CMR can be supplied as per direction of the manufacturer's recommendation. When the commercial CMR fed properly, high quality milk replacers will allow calf growth and performance equal or even greater than that attainable with whole milk. The preparation of CMR must be done with care, respecting concentration, water quality, hygiene of mixing and serving

equipment and mixing temperature. A typical milk replacer contains 70-80% milk solids, 17-20% animal and vegetable fats (e.g. tallow), 2% lecithin, traces of minerals (copper, zinc, manganese, cobalt, iron and iodine) and vitamins (A, D, B<sub>12</sub>, K and E) with added antibiotics or antibacterial drugs.<sup>1068</sup> However, adding of antibiotic is discouraged in modernly managed calf rearing.<sup>1066</sup>

### **Advantages of CMR**

- Advantages include ease of use, biosecurity and economic benefits
- Significantly improve the marketability and profitability of milk
- Grow more healthy calves and significantly reduces risk of disease e.g. Johne's disease, Bovine virus diarrhea and the cost of drugs and veterinary services
- Consistency of products when mixed correctly- less risk of digestive upsets and scours

### **Disadvantages of CMR**

- Lower energy due to fat content compared to take over milk
- Products with plant-based proteins have a lower digestibility in calves less than 3 weeks of age.

### **Calf starter (Starter concentrate)**

The newborn calf has a small undeveloped rumen and it does not contribute to digestion. The purpose of calf starter is to transition the calf from the milk-feeding period to the dry-feeding period. The intake of concentrate and water provide the rumen microbes with the nutrients they need to grow and multiply. Calf starter should be offered to calves starting at 3 days of age. After three weeks of eating starter concentrate, the rumen will have enough microbes to ferment the feed to supply the calf with energy.

Calf starter should be offered from day one and can be provided as a pellet or coarse feed and should be highly palatable to encourage early intake. The particle size of the starter concentrate should be 3 cm pellets and should be larger than 1.19 mm in diameter to avoid ruminal parakeratosis and bloat. It should not be powdery or dusty as this will reduce intake. Calf starter should provide around 18% crude protein to aid microbial growth and promote intake (Table 47). Calves eat only small amounts in the first two weeks but intake begins to increase measurably around 14 days of age.

### **Forage feed**

Forages are good source of fiber which promotes the growth of the muscular layer of the rumen and helps maintain the health of the rumen lining. In addition to calf starter, good quality forage should be offered as early as day three. Feed racks and buckets should be located at a height that is suitable for calves and positioned so as to reduce possibility of soiling.

### **Water supply**

Water accounts for 70-75% of a calf body weight and calves will perform best with fresh drinking water available to them from birth. Drinking water is required to support the rumen microbial population and promote good rumen development and function. Fresh water should be provided in addition to milk or milk replacer. Calves will drink 1.0 liter of water per day during the first week of life, increasing to nearly three times by 3-4 weeks of age. Providing drinking water in addition to milk replacer can increase growth by 38% and calf starter intake by 31%. Providing lukewarm water (16-18 °C) during cold weather may stimulate starter intake.

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SN Nutrient	Amount	SN Nutrient	Amount	SN Nutrient	Amount
01. Crude protein, %	16-20	02. Calcium, %	0.7	03. Phosphorus, %	0.45
04. Potassium, %	0.65	05. Copper, ppm	10	06. Zinc (ppm)	40
07. Manganese. ppm	40	08. Cobalt, ppm	0.1	09. Selenium, ppm	0.3
10. Vit. A, iu/lb DM)	1818	11. Vit. D, iu/lb DM	270	12. Vitamin E iu/lb DM)	12

The newborn calf has rudimentary stomach and during the first weeks of life is considered a monogastric animals. The neonatal calf must receive the correct diet based not only in its nutritional requirement but also in what is required for rumen development and transition to a functional ruminant. Table 48 shows the summary of the different experiments which have been conducted on milk replacers and calf starter with native and cross-bred calves for a period of 90 days.

Year	Research objective	Major findings	References
1968	Calcium and phosphorus supplement for the growth of calves	Calcium and phosphorus supplement have been reported to be required for growth and 2.0% level of steamed bone meal has reported superior to 1.0% for the purpose.	1069
1972	To evaluate a starter mixture in Sahiwal male calves	The starter mixture composed of 2 parts of Til oil cake and 1 part each of wheat bran and crushed khesehari. Starter mixture supplemented with Vitamin A 300 iu & D 1000 iu + TM-5 (1.5 lb/100lb) resulted higher average weekly LWG (4.4lb) than without Vitamin A + D (4.1lb) and without any TM-5 (3.7lb)	1070
1975	To evaluate four different formulation of calf starter In Sahiwal male calves	The average weekly LWG has reported significantly higher in calves fed starter mixture (SM) supplemented with TM-5 + Vit. A 300 iu and D 1000 iu (4.70lb) than only fed SM (2.60lb), SM + TM-5 (3.90 lb) and SM + Vitamin A + TM -5 (4.30 lb). Thus, SM + TM-5 + Vitamin A and D in liquid feed found effective.	1071
1978	To evaluate different feeding schedule of different groups of calves from birth to 90 days of age	Five groups (A-E) of calves have been used with four different formulations (B-E) by keeping control A which received colostrum (1-4 d), whole milk (5-90 d) and starter mixture (3lb/day) with green grass (Napier & Para) <i>ad libitum</i> as control. No significant differences on average LWG from consumption of different composition of milk replacer, calf starter and green grass have been reported among groups B-E groups.	1072
1985	To evaluate different feeding schedule of different groups of calves from birth to 90 days of age	Whole milk has supplied to calf @ 0.5 kg/ 5 kg BW up to the age of 21 days. Starter mixture has allowed to all calves beginning from 2 weeks of age with limit up to 1.5 kg daily per head and Napier / Para grass has supplied to all calves on <i>ad libitum</i> basis. The feed efficiency of the calves of groups B-E did not differ significantly but lower than those of group A.	1073

1987	To find out the effective starter mixture (SM) for crossbred calves up to one year of age	Six groups of cross-bred calves fed six different combination of SM to find the best effective one. Calves in Gr. A fed SM including wheat bran 45.45%, groundnut oil cake 45.45%, fish meal 13.63%, molasses 9.09%, steamed bone meal 1% and common salt 1.0% showed higher feeding value in terms of LWG (113.2kg).	1074
1987	To find out the effective composition of calf starter up to 90 days of age	Four different groups (A-D) of calves fed four different combination of calf starter mixture keeping Gr. A as control. Better performance has been reported in calves of control group A (wheat bran 45%, til oil cake 33%, fish meal 20%, steamed bone meal 1% and common salt 1%) without adding shoti powder (Table ?).	1075
1988	To find out the milk replacers for crossbred calves for a period of 90 days with local ingredients	Five groups (A-E) of calves have been selected at birth and fed in five treatment groups separately. Each of the calf of all the groups have supplied colostrum for 4 days, whole milk @ 0.5 kg/ 4.5 kg BW for two meals, 1.4 kg calf starter, and green grass (Napier & Para) but no milk replacer in Gr. A. Highest average LWG (2.55 kg/ week) has obtained in Gr. A fed without milk replacer than fed with milk replacer (1.63, 1.39, 1.31 and 1.61 kg/week).	1076
1990	To evaluate the six different formulations to find out the suitable starter mixture for cross-bred calves	Out of six starter mixture, mixture fed to Gr. A which include wheat bran 45.36%, ground-nut oil cake 45.36%, fish meal 13.61%, molasses 9.07% steamed bone meal 1.0% and common salt combination mixture has resulted weekly highest LWG 4.32 kg) than other groups.	1077
1992	To evaluate the three different calf starter mixture to determine the effective feeding regimes growth pattern of calves up to 3 months of age	All the three treatment groups (T-0, T-1 and T-2) have supplied similar feed ingredients including wheat bran 50%, rice bran 12%, khesari bran 30% and til oil cake 8%. In addition, calves of Gr T1 received 20% and T-2 received 40% leucaena leaf meal (g/d). Higher overall LWG (g/d) has been reported with T-0 group (278.58g) than T-1 (268.0g) and T-2 (273.3g).	1078
1993	Genetic potentiality of different crossbred calves	The genetically potentiality of Jersey calves have been reported to be slightly better than those of Sahiwal and Sindhi cross cows	1079
1994	To evaluate five groups of starter mixture (SM) to find a more effective SM for growing calves	Six different formulations of SM have been evaluated in six different groups of calves (A to F) from 2 <sup>nd</sup> week of their age <i>ad libitum</i> . A mixture of Napier and para grasses (1:1) has been supplied in all the groups on ad libitum basis. The best result obtained by Gr. A (50.01kg LWG at 90 days) may be due to use of molasses and the lowest LWG obtained by Gr. B (33.4kg) may be due to the use of shoti powder. The best result obtained by Gr. A with nutrients (in kg) included wheat bran 100kg, ground-nut oil cake 100kg, fish meal 30 kg, molasses 20kg, steamed bone meal 1.0 kg & salt 1.0kg.	1080
2009	To evaluate the utilization of soymilk as milk replacer for raising cross-bred dairy calves	Three groups (A,B & C) of crossbred dairy calves, of which Gr.A fed cow whole milk, Gr. B fed strained soy milk and Gr. C fed unstrained soy milk @ 1 liter / calf twice times daily for 8 weeks. Authors have suggested that soy milk could be used as a milk replacer successfully for raising the dairy calves.	1081

2011	Effect of feeding shoti based calf milk replacer	A trial research has been conducted under both on-station on-farm condition for the development of cost effective shoti based milk replacer	1082
2020	To evaluate plant sources to develop CMR based growth performance	The shoti and soybean based CMR have been reported to be maintained growth of calves compared to wheat based CMR and milk fed calves.	1083

Plagiarism 1072 & 1073

### Composition of calf milk replacer with locally available ingredients

The primary nutrients in milk replacer are protein, fat, carbohydrates, vitamins and minerals. **Table 49** shows the composition of CMR with locally available ingredients. It appears from **Table 47** that shoti and soybean based CMR better compare to wheat based CMR and even milk fed calves. Authors have suggested to use this CMR in the smallholder farms as well as commercial dairy farms and even suggested to utilize this formula for commercial production. However, the plant protein sources are highly discouraged to use for the preparation of CMR as these are associated with digestive disturbances within 3 weeks of age of calves.<sup>1066</sup>

T1 = Wheat based (n = 6)			T2 = Shoti based (n = 6)			T3 = Soybean based (n = 6)		
SN	Ingredient	%	SN	Ingredient	%	SN	Ingredient	%
1.	Wheat flour	29.0	1.	Shoti powder	39.0	1.	Soy powder	08.0
2.	Soymeal	47.0	2.	Soymeal	50.0	2.	Soymeal	43.0
3.	Rice flour	13.0	3.	Soybean oil	09.0	3.	Rice flour	38.0
4.	Soybean oil	09.0	4.	DCP	01.0	4.	Soybean oil	09.0
5.	DCP	01.0	5.	Common salt	00.5	5.	DCP	01.0
6.	Common salt	00.5	6.	Vita-Min-premix	00.5	6.	Common salt	00.5
7.	Vita-Min-premix	00.5	-	-	-	7.	Vita-Min-premix	00.5
•	Total cost Tk / kg	52.69	•	Total cost Tk./kg	94.45	•	Total cost Tk./kg	51.11
•	Diarrhea	14.0	•	Diarrhea	12.0	•	Diarrhea	08.0

T = Treatment group    DCP = Dicalcium phosphate

The overall calf rearing scenario in Bangladesh is still remain in traditional practice in which more than 95% of dairy smallholder farmers overlook the scientific technology on calf management. Moreover, the smallholder and even commercial dairy farmers are permitted to rear their calves by the cows. Calves reared with their dam start grazing and ruminating at approximately three weeks of age and regularly graze with adult cattle at 4 to 6 months of age. These calves are mainly suffering from malnutrition followed by late rumen development, late maturity, late in estrus, decrease conception rate and low milk production that results in economic loss to the farmers. Commercial CMR has been manufactured and marketed in developed nations and even most of the developing countries but it has not yet been developed in Bangladesh.

### Composition of calf starter with locally available ingredients

The main purpose of feeding calf starter is to transition the calf from the liquid milk feeding period to the dry feeding period. Feeding of calf starter is very important to healthy rumen development, good body growth and successful weaning of the calf. Calves start consuming measurable amounts of solid feed at about 14 days of age and intake increases rapidly when milk rations are reduced or milk is withdrawn.<sup>1084</sup>

Calf starter is a balance concentrate mixture, comprising ground cereal grains, protein supplements, minerals and vitamins. Calf starter is usually supplied from the three days calf's age. Initially provide a handful of calf starter in a shallow bucket and then gradually increase the amount of calf starter as calves grow. Fresh calf starter and water supply should made available for optimal calf growth. Feeding calf starter and good quality leguminous hay (fodder) from early life stimulates early development of rumen papillae which favors digestion of larger proportion of fodder at an early age. When calves are consuming 1 kg of calf starter a day for three consecutive days, the weaning process can begin. Table 50 shows the composition of calf starter prepared with locally available ingredients in Bangladesh.

Table 50. Composition of Calf starter with locally available ingredients								
Four formulae of an experiment <sup>1075</sup>					One formula of an experiment <sup>1083</sup>			
SN	Ingredient	A (C)	B	C	D	SN	Ingredient	%
1	Wheat bran	45	42	28	21	1.	Broken wheat	10.0
2	Til oil cake	33	31	40	42	2.	Wheat bran	40.0
3	Fish meal	20	20	20	20	3.	Khesari	24.0
4	Shoti powder	-	5	10	15	4.	Til oil cake	15.0
5	Steamed bone meal	1	1	1	1	5.	Fish meal	03.0
6	Common salt	1	1	1	1	6.	Soymeal	05.0
	Crude protein %	21.20	21.16	21.18	21.14	7.	Common salt	00.5
	Crude fiber %	07.08	06.54	06.05	06.56	8.	DCP	00.5
<b>Performance of calves</b>						9.	Oyster cell	02.0
1	No. of calves used	4	4	4	4	Total		100
2	Weight at birth (kg)	18.6	19.1	19.1	18.6			
3	BW at 90 days (kg)	45.5	40.1	36.8	36.8			
<b>Feed cost / kg of grain</b>								
1	Green napier grass	0.4	1.0	0.59	0.4			
2	Calf starter	4.2	3.12	2.57	2.09			
<b>TOTAL</b>		<b>5.08</b>	<b>4.16</b>	<b>3.17</b>	<b>2.73</b>			

Different level of shoti (Indian Arrowroot: *Zodaria decumbens*) at 0,5,10 and 15 % used in a calf starter mixture fed calves up to 90 days of age. The performance of calves in terms of BW was better without shoti powder in control groups of calves. But the cost of feed /kg of grain was less when shoti was incorporated in the starter mixture. During the nursing period, the growth is significantly affected by calf genetics, birth weight, gender of calf, calving season, duration of nursing period, amount of milk or milk replacer intake, total starter intake, environmental temperature and care practices.<sup>1085</sup>

### **Navel disinfection**

The umbilical cord of a newborn calf is a potential source of infection. During pregnancy, its main purpose is to attach the unborn calf to the dam to provide nutrients. Many blood vessels lead directly from the navel to a calf's organs. If bacteria enter, they have easy access to vital parts of the calf's body. Consequently, as soon as possible after birth, the navel should be dipped in a 7.0% iodine-based solution after proper removal of debris or straw on the navel cord, if any. If more than 5.0% of calves develop navel infections, the calving pen and calf facility may need some deep cleaning and navel disinfection may need to occur more quickly after birth. The navel should be examined regularly for about a week after birth. It should be dry, soft and not painful.

### **Public health and environment of livestock rearing**

Livestock keeping at urbanized areas is increasing folds in rate now-a-days in Bangladesh. Urban livestock rearing practices has been reported to be associated with public health and environmental issues.<sup>1086</sup>

### **Culling of dairy cattle**

Culling cattle is very important in any cattle operation because a producer gets rid of those animals that are inferior to the genetic qualities of the herd, those that are no longer productive and those that have no value being in the cow herd any more.<sup>1087</sup>

There are too many definitions have been used for the culling of dairy cattle. Some of them are: The culling is the removal of a live cow from the farm for immediate slaughter and sale is the movement to another farm for future dairy purposes and assumed to exclude temporary ownership by traders who subsequently send animals for slaughter and mortality is the death of an animal on the farm whether euthanized or unassisted. Culling is the act of identifying and removing a cow from a herd and assuming a constant or expanding herd size, replacing the cow with another cow, often a first-lactation heifer.<sup>1088</sup> Culling is the departure of cows from the herd due to sale, slaughter or death which has been classified as voluntary or involuntary.<sup>1089</sup> Culling (exiting) is the departure of cows from the herd because of sale, slaughter, salvage or death.<sup>1090</sup> In most cases the cow that exits is replaced, thus replacement has been a useful synonym for the event. The term 'cull' refers to all cows that leave the dairy regardless of their destination or condition at departure. Some may object to including cows that are sold for dairy purposes as part of a general cull category, as the word 'cull' generally means to separate off for undesirable reasons. Cows removed from the herd is based on the destination of the cows after removal and these can be placed into three groups: (a) Dairy sale- sale in the context of culling means that the cow is sold alive to another dairy with the expressed goal of continuing to provide income, such as producing milk, calves, (b) Slaughter-Salvage- means that the cow left the dairy alive to be slaughtered for human consumption and (c) Death (died, dead)- means that the cow died on the dairy.<sup>1090</sup>

Cows that involuntary culling implies that cows are culled due to disease, injury, infertility or death whereas the voluntary culling implies low yield or cows surplus to herd requirement when animals are healthy and farmer has complete freedom of choice over which cows are removed from the herd. Culling has also been classified based on reasons as either biological or economic. Biological (forced) culls are those cows for which no possible productive feature exists, like

permanently sterile, irreparably injured, positive for tuberculosis and brucellosis, whereas economic mean that cow is removed because a replacement is expected to produce greater profit.<sup>1091</sup>

Reproduction (e.g., failure to conceive) has been recognized as the primary cause of culling, secondly production and thirdly mastitis in USA.<sup>1092</sup> Highest culling has been reported caused by infertility, followed by mastitis in Iran.<sup>1091</sup> Review of available inland literature reveals that only two articles on culling dairy cattle have been published based on breeds of cattle<sup>1093</sup> and age of cows<sup>1094</sup> from BAU Dairy Farm of Bangladesh (Table 51 & 52).

A total of 238 animals have been culled, with annual culled rate 10.50, 7.98, 13.03, 7.56 and 60.92% in Pabna, Sahiwal, Sindhi, Red Chittagong and cross-bred cows respectively. Among all the breeds the highest percentages of culling rates reported in cross bred-cows (Table 51). The highest culling rate recorded in Pabna variety probably due to short lactation period and long calving interval. Red Chittagong cattle showed the second highest percentages in disposal for low production (22.2%). Highest culled rate caused by death due to parasitic diseases have been reported in crossbred (22.0%) in comparison to other breeds (Table 51). Mastitis has been highest in Sahiwal as the first cause for disposal of the animals. Tables 51 and 52 show highest culled rate of dairy cows due to parasitosis (22.0%), followed by pneumonia (13.10%), reproductive disorders (15.2%) and low milk production (8.3%). Table 52 shows that the highest culled rate has been reported in old aged cattle in comparison to other age groups. Dairy farmers should be encouraged to record and monitor disease events and reproductive performance and use these information as the basis for management efforts aimed at reducing the need to replace cows.<sup>1090</sup>

Table 51. Etiology of culled dairy cows (n = 238) at BAUDF during the period from 1971-1983<sup>1093</sup>

SN Etiology for culling	Pabna	Sahiwal	Sindhi	Red CTG	Cross-bred
01. Low production	36.0	05.1	03.2	22.2	08.3
02. Reproductive disorders	12.0	10.5	16.1	16.7	15.2
03. Mastitis	0	15.9	13.2	0	03.4
04. Emaciation	04.0	05.3	03.2	11.1	04.8
05. Deformed body conformation	0	0	03.2	0	03.0
06. Udder trouble	0	0	0	0	0
07. Old age	16.0	26.3	22.6	27.8	03.4
08. Injury	0	0	0	0	00.7
09. Other reasons	0	0	06.4	0	11.0
10. Parasitic diseases	12.0	10.5	16.1	11.1	22.00
11. Pneumonia	0	05.3	06.4	05.6	13.1
12. Reproductive disorders	08.0	05.3	03.2	0	01.4
13. Bloat	0	0	03.2	0	00.7
14. Anthrax	0	05.3	0	0	02.1
15. Old age	08.0	10.5	09.7	05.6	00.7
16. Haemorrhagic septicemia	04.0	0	03.2	0	04.1
17. Other reasons	0	0	0	0	05.5

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Table 52. Age-wise culling of cross-bred dairy cows at BAUDF during 1974-1983<sup>1094</sup>

SNCategories & Causes	Age of cows (years), No. %						Total
	Up to 3	>3- 4	>4-5	>5-6	>6-7	>7	
<b>A. Sold</b>							
1. Low production	-	-	-	25.0	08.9	19.6	12 (08.3)
2. Reproductive disorders	-	27.8	29.4	-	42.9	13.0	22 (15.2)
3. Mastitis	-	-	05.9	-	-	08.7	05 (03.4)
4. Emaciation	-	-	05.9	-	-	10.9	07 (04.8)
5. Deformed body conformation	07.2	05.6	-	12.5	-	-	05 (05.5)
6. Old age	-	-	-	-	-	10.9	05 (03.5)
7. Injury	-	-	-	-	-	02.2	02 (01.4)
8. Others	-	27.8	11.4	37.5	22.4	06.5	15 (10.3)
<b>B. Dead</b>							
1. Parasitosis	52.4	11.4	11.8	11.5	-	10.9	32 (22.0)
2. Pneumonia	33.3	16.7	-	12.5	09.5	-	19 (13.1)
3. Reproductive disorders	-	-	-	-	-	04.3	02 (01.4)
4. Blat	02.4	-	-	-	-	-	01 (00.7)
5. Anthrax	-	-	11.8	-	-	02.2	03 (02.1)
6. Old age	-	-	-	-	-	02.2	01 (00.7)
7. Haemorrhagic septicaemia	-	11.0	11.8	-	-	04.3	06 (04.1)
8. Others	04.7	-	11.4	-	16.3	04.3	08 (05.5)
<b>Overall. %</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>145</b>

### Manure management and biogas production

Some definition and terminologies related to manure which include: **manure**- broadly refers to dung of farm animals and poultry, either sole or added with urine, waste water, feed waste, litter / bedding materials, **animal slurry** is the manure of feces, urine, waste water and sometimes feed residues and bedding materials, which contain variable moisture contents 90 to 95%, **bio-slurry** is the semisolid by-products from biogas plant after anaerobic digestion of manure, **composting** is a manure treatment system which can be used to produce a stabilized product that is free from odor, harmful coliforms and fly problems, and **biogas** which is produced through anaerobic digestion of biological materials including livestock manure. Farm animals annually produce about 151.3 million tons of fresh manure, of which 3.08 tons/ year is produced under Milk-vita areas and other commercial farms in Bangladesh. Traditional management system of manure is considered as waste that pollutes air, water and soil that poses a threat to public health. The cattle manure is usually managed as (a) solid storage (56.2%), (b) liquid slurry (1.65%), (c) burned fuel (37.3%) and (d) anaerobic digester (4.80%) in Bangladesh.<sup>1095</sup>

Livestock manure pollutes environment through emitting greenhouse gases (GHGs) estimated to be 9.5% of the total of livestock origin.<sup>1096</sup> It has been reported that 56.2 to 57.0% manure of large ruminants is kept in solid storage, 37.3 to 43.0% as burned fuel, 4.8% is used in anaerobic digestion and 1.65% is lost as liquid slurry.<sup>1097</sup> The total annual methane emission from manure is estimated to be 176.75 Gg and emission from cattle manure 87.85% in Bangladesh.<sup>1097</sup> The

cattle dung, poultry litter and town cattle market straw have been reported to produce biogas yields of 0.034, 0.030 and 0.142 m<sup>3</sup> / kg with methane concentrations of 60%, 62% and 74% respectively.<sup>1098</sup>

Bangladesh remains far behind its neighbor countries in developing biogas as an alternative to conventional fuel. India has established 4.0 million biogas plants, 8.0 million in China and 80,000 in Nepal whereas it is only 10,000 in Bangladesh.<sup>1099</sup> Cattle dung available from 22 million large ruminants is nearly 0.22 million tons. One tone dung can produce 37 m<sup>3</sup> of biogas. Available cattle dung can produce  $2.97 \times 10^9$  m<sup>3</sup> of gas which is equivalent to  $1.52 \times 10^6$  ton kerosene or  $3.04 \times 10^6$  tons of coal.<sup>1100</sup>

The dung is mixed with water in equal ratio and stored in a tank. After 10 to 12 days biogas is produced in the plant which is supplied to the ovens through plastic pipes.<sup>1099</sup> Biogas is a combustible gas produced by anaerobic digestion (AD) and fermentation of organic materials by the action of methanogenic bacteria in a wet process: the dung is mixed with water and left to ferment in an enclosed vessel. The resultant gas which is emitted is mainly composed of methane (60-70%) and carbon dioxide (30 to 40%)- a very similar composition to piped gas in towns, which is derived from fossil fuels. Methane based gas produces more heat than kerosene, fuel wood, charcoal and dung-cake.<sup>1101</sup>

Limited inland research reports on biogas production and management system has been published from Bangladesh.<sup>1102-1104</sup> An investigation study showed that 85% biogas plants are functioning at full capacity whereas 15% are not functioning at all in the district of Tangail.<sup>1105</sup> A designed project has been suggested to produce 18 MW electricity and 72 ton bio-fertilizer annually from biogas in Bangladesh.<sup>1106</sup> Biogas technology is one of the best means to provide natural gas to the largest number of rural people which can provide them with pollution free, efficient energy for cooking and at the same time protect them from dung-borne diseases by giving them a clear environment.

### **Miscellaneous research findings**

Design of an ideal stanchion dairy barn,<sup>1107</sup> participation of rural people in cattle management,<sup>1108</sup> non-genetic effects on birth weight,<sup>1109</sup> colostrum and transition milk,<sup>1110</sup> effect of parity on calving pattern,<sup>1111</sup> influence of season on birth,<sup>1112</sup> sex ratio of calves,<sup>1113</sup> genetic lift in the birth weight,<sup>1114</sup> growth curves of local  $\times$  Jersey,<sup>1115</sup> body weight and milk yield,<sup>1116</sup> milk production trend and F1 crossbred cows of Milk-vita,<sup>1117,1118</sup> chemical and microbial qualities of morning and evening milk,<sup>1119</sup> lactation milk record,<sup>1120</sup> milk yield and composition of RCC,<sup>1121,1122</sup> relationship of milk vein and milk production,<sup>1123</sup> nutritional content and bacteriological contamination and analysis of milk,<sup>1124,1125,1126</sup> evaluation of fermented milk-wheat flour,<sup>1127</sup> preparation of fermented beverage from whey-based watermelon,<sup>1128</sup> utilization of whey in fermented and non-fermented drinks,<sup>1129</sup> preservation of butter,<sup>1130</sup> lactic acid bacteria in dahi,<sup>1131</sup> limitation of crossbreeding,<sup>1132</sup> comparison of dairy traits of crossbred cows,<sup>1133</sup> variation of morphological features and growth of Pabna cattle,<sup>1134</sup> supplementation of fish meal on growth and reproductive performance,<sup>1135</sup> production of cowpea forage,<sup>1136</sup> maize fodder production,<sup>1137</sup> identification of naturally available forage species,<sup>1138</sup> importance of vitamin A in dairy cattle,<sup>1139</sup> productive and reproductive performance of dairy cows,<sup>1140-1149</sup> genetic and phenotypic parameter on fertility traits,<sup>1150,1151</sup> genotype and environment interaction in growth

trait,<sup>1152</sup> genetic evaluation of BLRI cattle,<sup>1153</sup> breeding soundness of stud bulls,<sup>1154</sup> evaluation of semen of Brahman bulls,<sup>1155,1156</sup> AI and pregnancy rate,<sup>1157</sup> suitability of temperature and tropical crossbred of cattle,<sup>1158</sup> cow feces for *in vitro* digestibility assay of forages,<sup>1159,1160,1161</sup> *in vitro* digestibility of hay,<sup>1162</sup> wheat bran supplementation in native bulls,<sup>1163</sup> feeding of urea-molasses straw based diet,<sup>1164,1165,1166</sup> urea-molasses multi-nutrient blocks in rural cattle,<sup>1167</sup> lime treated rice straw,<sup>1168</sup> moringa oleifera leaf as protein supplement,<sup>1169</sup> frequency of feeding on growth and carcass characteristics,<sup>1170</sup> psychrophilic bacteria in dairy barns,<sup>1171</sup> livestock credit,<sup>1172</sup> profitability of loaned dairy farms,<sup>1173,1174</sup> livestock technology<sup>1175</sup> and biotechnology,<sup>1176</sup> matching technology in flood affected area,<sup>1177</sup> urine collecting device,<sup>1178</sup> evaluation of milk urea nitrogen,<sup>1179</sup> manure yield by cattle and buffalo,<sup>1180</sup> preparation of hygienic compost,<sup>1181</sup> garbage waste induced heavy metals on roaming cattle,<sup>1182</sup> statistical analysis of some economic traits of cattle,<sup>1183</sup> indigenous knowledge on livestock practices,<sup>1184</sup> and quality of chocolate milk made of different source of fat and solid-not-fat.<sup>1185</sup>

### **Limitations due to inappropriate data and plagiarism**

Review of inland published reports on cattle production, management and dairy products reveals that the repetition of research works have been practiced, moreover multiple articles have been published with same data or in duplicate in the same and different journals especially feeding practices of draught animals,<sup>81,82</sup> cow feces has been used as a source of microorganisms for *in vitro*<sup>304</sup> and *in vivo*<sup>307,312</sup> digestibility, reproductive parameters of L × HF cows,<sup>752,753</sup> feeding schedule of different groups of calves from birth to 90 days of age<sup>1072,1073</sup> and same dairy farm data published as breed-wise<sup>1093</sup> and age-wise<sup>1094</sup> culling of dairy cattle in different journals. Authors, reviewers, editors, academicians, readers and science community need a more caution approach to deal these types of articles. This article at least would help to identify the future plagiarism on the submitted articles before publication in different journals.

### **CONCLUSIONS**

The status of cattle breeds and varieties with their characteristics, productive and reproductive performances, feeds and fodder production, fattening of cattle and beef production and milk production and milk products, semen collection and crossbreeding by AI, economics of dairy farming and calf rearing with milk replacer and calf starter have been reviewed. It appears from this review that HF × L crossbred cows has been suggested for highest profit, feeding of German fodder for maximum milk production, AI at the mid-cycle (12 to 15 hours) for highest CR (80.36%) and higher birth weight in male calves than female calves.

### **ETHICAL APPROVAL**

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

### **CONFLICT OF INTEREST**

The author declares that this review work was completed without any commercial or financial relationships that could be construed as a potential conflict of interest.

## ACKNOWLEDGEMENTS

The author would like to express very greater appreciation to all the authors especially animal husbandry scientists, animal science scientist, veterinary medical scientists, biological scientists, zoologists, journalist and cattle extension specialists who have contributed and published research articles on the cattle production, management and dairy products in the national and international journals and websites during the last six decades (1962 to 2020) from the then East Pakistan and Bangladesh that are used as the source of this review article.

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