

RESEARCH ARTICLE

Dairy Science

A preliminary study on milk composition of three buffalo breeds located in Polonnaruwa, Sri Lanka

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Abstract: Buffaloes have great potential to be developed as one of the main dairy animals in Sri Lanka because of their higher adaptability to local conditions compared to European dairy cattle breeds. Processing dairy products such as curd, cheese, and yoghurt from buffalo milk has several advantages due to its greater quantities of total solids, solid-nonfat, and protein. However, milk composition and coagulation properties largely depend on the breed. Therefore, this research aimed to investigate the milk composition of three major buffalo breeds in Sri Lanka. The milk of the Lanka buffalo contained 18.1% total solids, 10.7% solid non-fat (SNF), 7.5% fat, 4.9% protein, 4.9% lactose, and 0.9% minerals. The milk of the Murrah crossbreed contained 15.4% total solids, 10.1% SNF, 5.3% fat, 4.2% protein, 5.1% lactose, and 1.1% minerals. The milk of the Nili-Ravi crossbreed contained 16.6% total solids, 10.2% SNF, 6.4% fat, 4.1% protein, 4.9% lactose, and 1.1% minerals. The results indicate that milk composition varies among the breeds in which the milk of the Lanka buffalo has significantly higher amounts of total solids, SNF, and fat. Protein, lactose, and mineral contents do not vary significantly.

Keywords: Buffalo milk, Lanka buffalo, milk fat, milk protein, Murrah, Nili-Ravi.

INTRODUCTION

The milk production of the world is supplied by only a few species of dairy animals. Among them, buffalo

(*Bubalus bubalis*) is the second largest milk-producing species after cattle. Buffaloes produce approximately 15% of the world's milk production. In developing countries, one-third of the total milk production comes from species other than cattle (e.g., 40% in Asia and 23% in Africa), mostly from buffaloes (FAO, 2023). South Asia is inhabited by approximately 78% of the global buffalo population and currently produces about 100 million metric tons of buffalo milk which accounts for about 93% of the world's buffalo milk production (Siddiky & Faruque, 2018). The share of buffalo milk is approximately 51% of the total milk production in South Asia. The contribution of buffalo milk to the total milk production of Nepal, Pakistan, and India is 67%, 60%, and 51%, respectively (Siddiky & Faruque, 2018).

Buffaloes are generally distributed in Asia, the Middle East, and Europe and are mainly divided into two sub-species: River-type and Swamp-type (Abdel-Hamid *et al.*, 2023). River-type buffaloes have been developed mainly in the Indian subcontinent and are used for milk production. Swamp-type buffaloes are mainly used for draught and meat production but are poor milk producers (Han *et al.*, 2007). Buffaloes can be used as dairy animals mainly in wet tropical regions in the world including South Asia (Bittante *et al.*, 2022; FAO, 2023). They

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are unique in their way of surviving during very hard nutritional conditions as well as under less beneficial management. This makes them well suited not only to tropical environments but also to where specialized dairy cows have difficulties in adapting to the conditions (Khan, 2002; Hallqvist, 2019; Bittante *et al.*, 2022). Due to these beneficial traits, buffaloes are considered the dairy animal for the 21st century. There is a large diversity in buffalo genetic resources and South Asia is home to many high-yielding buffalo breeds such as Murrah and Nili-Ravi (Siddiky & Faruque, 2018).

Buffalo milk has a growing demand and popularity because of its flavour, and high content of protein, fat, vitamins, lactose, total solids, and other nutrients compared to cow milk (Han *et al.*, 2007; Bittante *et al.*, 2022; Abdel-Hamid *et al.*, 2023). Therefore, buffalo milk receives increasing research interest and investment opportunities owing mainly to its attractive nutrient content (Han *et al.*, 2007). Milk processing allows milk to be preserved for extended periods ranging from days to years while helping reduce the incidence of food-borne diseases and making it consumable for people with lactose intolerance, which affects about two-thirds of the human population (Lomer *et al.*, 2008; Bittante *et al.*, 2022; FAO, 2023). Buffalo milk has been utilized to produce a large variety of commercial dairy products and numerous novel dairy-based products are also being researched. These products include yoghurts (Hekmat & Reid, 2006; Akgun *et al.*, 2016; 2018), probiotic and symbiotic yoghurts (Han *et al.*, 2012; Nguyen *et al.*, 2014; Ehsani *et al.*, 2016; Yapa *et al.*, 2023), fortified yoghurts with different additives such as mango pulp and soymilk (Kumar & Mishra, 2007), apple fruit and honey (Ghadge *et al.*, 2008), and bael fruit pulp (Yapa *et al.*, 2023), dairy beverages (Silva *et al.*, 2020), ice cream (Roy *et al.*, 2021; Sert *et al.*, 2021) and curd (Priyashantha *et al.*, 2021). Differences found between buffalo milk and cow milk provide unique characteristics and processing capabilities to the dairy products processed from buffalo milk. Milk produced by buffaloes has the highest total solids and fat content, as well as the greatest casein/protein ratio of the six major dairy species (Roy *et al.*, 2021; Bittante *et al.*, 2022). Because of this, buffalo milk was reported to yield more fresh cheese (25%) than ewe (22.9%), cow (15.4%), dromedary (13.8%), and goat (11.9%) milk. This is largely due to the greater fat and protein contents of buffalo milk in addition to the greater recovery of fat (88.2%) in the curd (Bittante *et al.*, 2022). Moreover, the coagulation and curd-firmness patterns of buffalo milk were reported to be excellent. Buffalo milk had the highest recoveries in the curd of fat and energy, and also had the highest cheese-making efficiency among

the 6 major dairy species, retaining as much as 76% of milk energy in cheese (Bittante *et al.*, 2022). More importantly, unlike other species, the cheese-making efficiency of buffaloes was found to be unaffected by the parity but increased with the advancing stage of lactation (Bittante *et al.*, 2022). Higher cheese yield from buffalo milk partly compensates lower daily milk yield of buffaloes compared to specialized dairy cattle breeds (Sun *et al.*, 2014).

The composition of milk from dairy buffaloes is of major interest to milk producers, processors, and consumers, since the concentration of certain milk components influences the pricing policy in the market and directly affects the economy of milk production as well as the economic conditions of the farmers (Boro *et al.*, 2018). Knowing the composition is also useful for the manufacture of a wide variety of specialty dairy products (Han *et al.*, 2012). Milk composition affects milk gelation characteristics, yield and quality of cheese (Glantz *et al.*, 2010), foaming properties of milk (Huppertz, 2010), and milk processability (O'Brien *et al.*, 2002). The general composition of milk is an essential consideration for variation in milk coagulation properties and is important for selecting desired dairy breeds for manufacturing cheese and yoghurt-like products (Abeykoon *et al.*, 2016). Although Sri Lanka has favorable climatic conditions and other necessary resources for buffalo production, its true potential has not yet been realized. Buffaloes can effectively be utilized to uplift milk production in the country where the current production level can only be sufficient to fulfill about 40% of the demand. When the other countries in the region (e.g., Nepal, Pakistan, and India) managed to produce more than 50% of their total milk production from buffaloes, Sri Lanka only managed to produce just over 15% accounting for approximately 56 million liters in 2021 (DAPH, 2021), which is far below its true potential. Although the detailed chemical composition of milk from different buffalo breeds has been studied in many countries considering its importance from an industrial point of view, such a detailed study is absent in Sri Lanka to the best of our knowledge. One comprehensive report is available on milk coagulation properties and milk protein genetic variants of three cattle breeds/types in Sri Lanka (Abeykoon *et al.*, 2016). In relation to buffaloes, milk yields and lactation performances of some major buffalo breeds in Sri Lanka have been documented (Ibrahim & Jayatileka, 2000; Nafees & Jeyamalar, 2005; Dematawewa & Dekkers, 2014; Charlini & Sinniah, 2015). In one study, only the milk composition of the local/Lanka buffalo has been documented (Horadagoda, 1990) and two more studies reported the milk composition of buffalo without

specifying the breeds (Mahanama, 2008; Randiwela *et al.*, 2018). In this context, the current study aimed to analyze the milk composition of three major buffalo breeds in Sri Lanka namely local/Lanka buffalo, and the crossbreeds of Murrah and Nili-Ravi.

MATERIALS AND METHODS

Sample collection

Milk samples from the indigenous breed/Lanka buffalo and Murrah (Murrah × Local) and Nili-Ravi (Nili-Ravi × Local) crosses were collected from a semi-intensively managed buffalo farm located in the Wadigawewa area in the Polonnaruwa District of Sri Lanka. This farm was selected since it reared all the breeds and crosses considered in the current study. Collecting all the milk samples from the same farm allowed us to make fair comparisons among the breeds as feeding and other management practices are the same. If the samples were collected from several farms, feeding, and management practices may be different from farm to farm leading to greater compositional changes in milk obtained from different farms. Since the milk composition is also influenced by the season, parity number, and the stage of lactation, the milk samples for the current study were obtained from the buffaloes in the same parity number (3 or 4) and stage of lactation (mid-lactation, between 100 – 200 d of milking) during the month of October 2022. Accordingly, milk samples for analysis were collected from 10 lactating buffaloes from each breed (altogether 30 buffaloes) during morning milking. All the samples were collected on the same day. Milk samples were collected into plastic vials, sealed, and stored under refrigerated conditions (~4°C) until analysis. All the steps were conducted hygienically to avoid any contaminations. Buffalo breeds were identified based on the morphological characteristics unique to each breed and confirmed by the breeding records of the animals.

Determination of milk components

The fat, protein, and solid non-fat (SNF) contents of the milk samples were determined by an automatic milk analyser (MilcoScope, Julie Z9 Automatic, Scope Electric) established at the Nestle Lanka Kurunegala Factory at Pannala. The values obtained by the equipment were validated against the standard AOAC methods to determine protein (method 939.02) and fat (method 2000.18) contents to confirm the accuracy. Milk lactose content was determined by the iodometric

method. Briefly, 10 mL of milk portion was transferred to a pre-weighed graduated flask and weighed. The milk sample was then diluted with 50 mL of distilled water followed by the addition of 10 mL of Mayer's Reagent (freshly prepared by dissolving a mixture of 1.36 g of mercuric chloride and 5 g of potassium iodide in 100 mL of distilled water) to precipitate proteins and fats. Then 2 mL of 1 N sulphuric acid was added, shaken well, and the solution was filtered. Twenty-five millilitres (25 mL) of this filtrate was then mixed with 20 mL of 0.1 N Iodine solution and 30 mL of 0.1 N sodium hydroxide. The solution was left in the dark for 20 min. Then 4 mL of sulphuric acid was added and the excess iodine was titrated with a 0.1 N sodium thiosulphate solution. The starch solution was added at the point of light yellow colour and the titration continued until the solution turned from deep blue to colourless. The amount of lactose was determined by multiplying the expended volume of 0.1 N iodine by 0.01705. The mineral content was determined by AOAC Method 930.30 (AOAC, 2019). The total solids content was determined by summing up the values for fat and SNF.

Statistical analysis

Statistical differences in milk components among different breeds are detected by performing a series of one-way analyses of variance (ANOVA). Means were separated by the Tukey Test. All statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago, IL) with a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Physicochemical characteristics such as milk components and pH are important parameters for the physicochemical and nutritional attributes of milk (Çinar *et al.*, 2019). Milk is composed of water, proteins, fat, lactose, vitamins, and minerals. Milk solids are composed of the four major milk components namely, protein, fat, lactose, and minerals. On the other hand, the milk solid non-fat (SNF) portion comprises protein, lactose, and minerals. These components perform different functions and physiological roles. Out of these, fat, protein, SNF, lactose, and mineral contents are the most economically important milk constituents (Boro *et al.*, 2018). In the current study, we examined the differences in milk constituents among three major dairy buffalo breeds in Sri Lanka. The total solids, SNF, fat, protein, lactose and mineral contents of milk of Lanka buffalo and crosses of Murrah and Nili-Ravi are summarized in Table 1.

Table 1: Major milk components of Lanka buffalo, and crossbreeds of Murrah and Nili-Ravi in Sri Lanka

Milk Component	Murrah cross		Nili-Ravi cross		Lanka Buffalo	
	Average (%)	Range (%)	Average (%)	Range (%)	Average (%)	Range (%)
Total solids	15.4 ± 1.9 ^a	12.9 - 17.6	16.6 ± 1.0 ^{ab}	14.8 - 18.3	18.1 ± 1.9 ^b	15.4 - 20.5
Solid non-fat (SNF)	10.1 ± 0.3 ^a	9.6 - 10.7	10.2 ± 0.3 ^a	9.9 - 10.7	10.7 ± 0.3 ^b	10.1 - 11.1
Fat	5.3 ± 1.6 ^a	3.2 - 6.9	6.4 ± 0.9 ^{ab}	4.9 - 7.5	7.5 ± 1.6 ^b	5.2 - 9.4
Protein	4.2 ± 0.5 ^a	3.7 - 5.1	4.1 ± 0.2 ^a	3.9 - 4.6	4.9 ± 0.6 ^a	4.0 - 5.5
Lactose	5.1 ± 0.3 ^a	4.5 - 5.5	4.9 ± 0.3 ^a	4.6 - 5.5	4.9 ± 0.2 ^a	4.5 - 5.2
Minerals	1.1 ± 0.3 ^a	0.3 - 1.5	1.1 ± 0.4 ^a	0.7 - 1.4	0.9 ± 0.4 ^a	0.4 - 1.7

Data are mean ± SD (n = 10 for each breed)

Averages with the same superscript letter in the same row did not show any significant difference (P > 0.05).

Total solid contents

The total solid content represents the solid portion of milk that is composed of milk fat, protein, lactose, minerals, and vitamins. The total solid content of milk varies according to the dairy species. For example, the total solid content of milk from buffalo, cattle, and goats is approximately 18%, 13%, and 12%, respectively (Bittante *et al.*, 2022). There is a positive correlation between total solid and fat contents in which higher fat contents always result in higher total solid contents (Tekelioglu *et al.*, 2010). The total solid content in milk has a crucial role in dairy products manufactured by removing water content (*e.g.*, whole milk powder) where higher total solid content results in proportionately greater quantities of the end product. In this sense, buffalo milk is advantageous over bovine milk since buffalo milk contains a greater content of total solids.

In the current study, the total solid content in the milk of individual animals ranged from 12.9% to 20.5%. The highest average total solid content (18.1 ± 1.9%) was found in the milk of Lanka buffalo. Milk from Murrah and Nili-Ravi crosses were 15.4 ± 1.9% and 16.6 ± 1.0%, respectively. The average total solid contents observed among the three breeds were within the range reported in the previous studies conducted in various geographical areas in the world including China, the USA, the Mediterranean region, and the Indian sub-continent (Han *et al.*, 2007; Sun *et al.*, 2014; Çinar *et al.*, 2019; Bittante *et al.*, 2022).

SNF content

The solid non-fat (SNF) portion of milk consists of all solids in milk (protein, lactose, minerals) other than fat. Milk with high SNF is valuable to the consumer for its flavour and nutritional value and to the manufacturer

of dairy products, especially related to cheese yield (Roberts, 1987).

In our study, the SNF contents in the milk of the Murrah crosses and Nili-Ravi crosses were comparable (10.1 and 10.2, respectively). However, the milk of Lanka buffalo showed significantly higher SNF content (10.7 ± 0.3%) than that of the crossbreeds. These results suggest that the milk of the Lanka buffalo is more advantageous than the milk of the Murrah and Nili-Ravi crossbreeds in cheese making as it may provide a comparatively higher cheese yield, due to higher SNF content. However, to the best of our knowledge, no study has been conducted to examine the milk coagulation properties of the buffalo breeds in Sri Lanka. More interestingly, the milk of the all buffalo breeds tested in the current study showed considerably higher SNF contents compared to that of the indigenous cattle breeds of Sri Lanka, Thamankaduwa white (9.45%) and Lanka cattle (9.44%) as well as the major dairy breed Friesian (8.87%) (Abeykoon *et al.*, 2016).

Previous studies conducted elsewhere in the world showed SNF contents ranging from 8.8% to 11.7% depending on the breed. In our study, the SNF contents varied from 9.63% to 11.05% in the individual animals used in the study and this range was in agreement with the previous studies (Table 2). The SNF contents of the milk from pure Murrah and Nili-Ravi were 9.34 – 11.21% and 9.70 – 11.10%, respectively. If crossbreeds are concerned, this ranged from 10.66% to 11.70%. Our results obtained for the crossbreeds were within the range of the pure breeds but slightly less than that of the crossbreeds. Most probably, these variations in SNF content may be due to the differences in the stage of lactation and the parity/lactation number reported in different studies (Dubey *et al.*, 1997; Yadav *et al.*, 2013). However, the milk of the three breeds concerned in our study showed considerably

higher SNF content than that of the two other prominent buffalo breeds in the Indian sub-continent, Mehsana ($9.13 \pm 0.06\%$) and Surti ($8.80 \pm 0.07\%$) (Misra *et al.*, 2008).

Milk fat content

Milk fat is often a major component of dairy products such as butter and related products, cream products, cheese, ice cream, infant milk formulas, and milk chocolates. Milk fat contributes to the structure, flavour, colour, mouth feel, texture, and functional behaviour of dairy products depending on the product category (Waldron *et al.*, 2020). Milk fat percentage shows a greater variation than any other constituent in milk (Roberts, 1987). The fat content in buffalo milk varies depending on the stage of lactation and parity/lactation number (Shah *et al.*, 1983).

In the current study, the milk fat content of the individual buffaloes ranged from 3.2% to 9.4%. Milk from Lanka buffalo showed the highest average milk fat content ($7.5 \pm 1.6\%$) and the lowest was observed in the milk of the Murrah crossbreed ($5.3 \pm 1.6\%$). The average milk fat contents for the Murrah crossbreed and Nili-Ravi crossbreed reported in the current study were lower than the values reported for pure Murrah ($6.57 - 7.82\%$) and Nili-Ravi ($6.53 - 9.22\%$) buffaloes in the available literature (Table 2). More interestingly, the values observed for the Murrah crossbreed were also considerably lower than the Murrah crossbreeds reported in the other studies. For example, Han and colleagues reported milk fat contents of approximately 6.5 – 10.6% for first- and second-generation Murrah \times Guangxi crossbreeds (Han *et al.*, 2007). A similar observation was made for the Nili-Ravi crossbreed as well, while the milk fat content reported in the current study was considerably lower than the values reported for various other crossbreeds (Table 2). Perhaps this variation may be due to poor nutrition, and differences in diet, stage of lactation, parity/lactation number, and geographical location. For instance, the fat content in buffalo milk tends to get higher progressively from 5.5% in the first month to 7.5% in the tenth month of lactation, coinciding with the decreasing milk yield with the progression of lactation (Shah *et al.*, 1983; Yadav *et al.*, 2013). On the other hand, the first lactation is said to be superior in terms of milk fat than that of successive lactations (Sundaram & Harharan, 2013).

Among the three breeds tested in the current study, only the milk fat content of the Lanka buffalo is in agreement with the values ($6.57 - 9.22\%$) in published literature (Table 2). Moreover, the fat content of the Lanka buffalo was found to be more than double that

of the Thamankaduwa white (3.84%) and Lanka/Local cattle (3.31%), two indigenous cattle breeds of Sri Lanka (Abeykoon *et al.*, 2016).

Milk protein

Milk coagulation is the primary step involved in the development of most dairy products and the coagulation properties of milk are largely influenced by protein content and composition (Abeykoon *et al.*, 2016). Proteins are among the least variable milk constituents and do not vary significantly during stages of lactation (Yadav *et al.*, 2013). Casein accounts for approximately 80 - 82% of the proteins found in buffalo milk (Dubey *et al.*, 1997; Bittante *et al.*, 2022).

The protein content in the milk of individual buffaloes used in the current study ranged from 3.7% to 5.5% which is in agreement with the range of protein contents reported in the literature (3.46 – 5.78%, Table 2). In the current study, all three breeds had comparable protein contents ($P > 0.05$) although that in the Lanka buffalo's milk was slightly higher ($4.9 \pm 0.6\%$). The protein content in the milk of the Murrah crossbreed ($4.2 \pm 0.5\%$) was within the range (3.47 – 4.92%) reported for the Murrah pure breeds in other studies. However, it was lower compared to the Murrah crossbreeds (5.51 – 5.78%) and other crossbreeds (4.75 – 5.23%). Values obtained for Nili-Ravi crosses were also within the range reported for Nili-Ravi purebreds (3.89 – 5.14%) but lower than that of the crossbreeds. As the protein content is least varied depending on the stage of lactation and diet, these differences may be due to the breed of buffalo or lactation/parity number. For instance, protein levels are reported to be high in advanced parities (Yadav *et al.*, 2013) and the third lactation is superior in terms of milk proteins (Sundaram & Harharan, 2013).

More interestingly, the average protein contents observed in the current study were higher than that reported for the local cattle breeds Thamankaduwa white (3.48%) and Local/Lanka cattle (3.47%) suggesting that buffalo milk contains more milk proteins than bovine milk (Abeykoon *et al.*, 2016).

Lactose

Lactose is the main carbohydrate in milk and drives the milk yield of the animal being a main determinant of the osmotic pressure of milk. Physical and chemical properties of lactose such as comparatively low solubility and specific crystallization behavior play a major role in the properties and quality of many dairy products and dairy-based ingredients.

Table 2: Composition of buffalo milk from different breeds and crossbreeds around the world

Breed	Total solids (%)	Fat (%)	SNF (%)	Protein (%)	Lactose (%)	Minerals (%)	Country	Reference
Murrah	17.01 ± 0.05	7.65 ± 0.05	9.36 ± 0.02	3.81 ± 0.02	4.83 ± 0.01		India	Dubey et al., 1997
		7.19 – 8.63		3.46 – 3.56	4.36 – 4.60		India	Yadav et al., 2013
	16.99 ± 0.12	6.99 ± 0.10	10.01 ± 0.06	3.78 ± 0.03	5.37 ± 0.04		India	Sarkar et al., 2006
	17.0 ± 0.1	7.7 ± 0.1	9.4 ± 0.1	3.81 ± 0.02	4.83 ± 0.01		India	Sodhi et al., 2008
	19.03	7.82	11.21*	4.92	5.18		China	Zhou et al., 2018
	18.23 ± 1.8	7.17 ± 1.7	10.34 ± 0.2	4.91 ± 0.2	5.25 ± 0.2		China	Abdel-Hamid et al., 2023
	16.69 ± 1.22	6.57 ± 1.21	10.12*	4.27 ± 0.43	5.07 ± 0.13	0.79 ± 0.05	China	Han et al., 2007
	17.07 ± 1.22	6.86 ± 1.28	10.21*	4.75 ± 0.36	4.60 ± 0.52		China	Sun et al., 2014
	17.44	6.77	10.67*	4.54	5.28		China	Zhou et al., 2018
	17.29 ± 1.6	6.84 ± 1.2	9.70 ± 0.5	4.38 ± 0.2	5.27 ± 0.3		China	Abdel-Hamid et al., 2023
Nili-Ravi	16.85 – 17.84	9.22 – 9.65	10.14 – 10.35	3.89 – 4.70	4.83 – 5.17	0.79 – 0.89	Pakistan	Faraz et al., 2021
	17.14 ± 1.34	6.53 ± 1.28	10.61*	4.16 ± 0.20	4.56 ± 0.10	0.81 ± 0.03	China	Han et al., 2007
	19.80 ± 3.05	7.99 ± 1.57	11.18*	5.14 ± 0.73	4.74 ± 0.81			Sun et al., 2014
	15.59 ± 0.18	6.46 ± 0.17	9.13 ± 0.06	3.87 ± 0.05			India	Misra et al., 2008
Mehsana	14.96 ± 0.21	6.17 ± 0.20	8.80 ± 0.07	3.93 ± 0.05			India	Misra et al., 2008
						0.8	Italy	Bittante et al., 2022
Mediterranean	17.93	7.71	10.22*	4.38	5.01		China	Abdel-Hamid et al., 2023
	20.18 ± 1.2	8.98 ± 1.2	10.17 ± 0.5	5.08 ± 0.5	4.98 ± 0.5			
Local/Lanka buffalo		7.45 ± 0.06	9.62 ± 0.46	5.16 ± 0.15	4.3 ± 0.02	0.72 ± 0.02	Sri Lanka	Horadagoda, 1990
	F1 crossbreed	19.75 ± 2.29	8.81 ± 1.89	10.94*	5.23 ± 0.45	0.88 ± 0.07	China	Han et al., 2007
F2 crossbreed	19.21 ± 1.56	7.90 ± 1.30	11.31*	5.10 ± 0.45	4.64 ± 0.54	0.85 ± 0.05	China	Han et al., 2007
	Multi-crossbreed	18.22 ± 1.24	7.56 ± 0.90	10.66*	4.75 ± 0.53	0.84 ± 0.06	China	Han et al., 2007
F1 crossbreed (Murrah × Guangxi)	20.05 ± 1.84	8.35 ± 1.72	11.7*	5.78 ± 1.14	4.59 ± 0.87		China	Sun et al., 2014
	F2 crossbreed (Murrah × Guangxi)	20.22 ± 2.54	8.69 ± 1.86	11.53*	5.51 ± 0.46	4.45 ± 1.00	China	Sun et al., 2014

*Estimated using the available data

There are two main roles of lactose: it acts as an energy source for the lactic acid bacteria that are used for fermented dairy products and as a precursor for specific flavour components (Hettinga, 2019). The stage of lactation significantly affects the lactose content in milk where it is significantly increased up to 4 – 6 months of lactation and decreased thereafter in buffaloes (Shah *et al.*, 1983; Yadav *et al.*, 2013).

The lactose content of milk of individual buffaloes used in the current study ranged from 4.5% to 5.5%, which is in agreement with the lactose content reported for buffalo milk in previous studies (4.36 – 5.37%, Table 2). The average lactose content was the same between the Nili-Ravi cross and Lanka buffalo (4.9%). Slightly higher, average lactose content was observed in the milk of Murrah crossbreeds ($5.1 \pm 0.3\%$). However, no statistically significant difference was found among the three breeds. The lactose content observed for Murrah and Nili-Ravi crossbreeds were compatible with the values reported for corresponding pure breeds (4.36 – 5.37% for Murrah and 4.56 – 5.28% for Nili-Ravi) and crosses (4.45 – 4.80%) in the previous studies.

Mineral content

The mineral content of milk is important nutritionally. Milk is a good source of minerals including calcium, phosphorus, magnesium, iron, iodine, and sodium. The mineral contents of the milk from Murrah and Nili-Ravi crossbreeds, and Lanka buffalo were comparable to each other ($P > 0.05$) although that in the Lanka buffalo ($0.9 \pm 0.4\%$) was slightly lower than the crossbreeds (1.1%). Unlike other milk constituents, the mineral content of buffalo milk has seldom been determined in previous studies. However, available data showed that the mineral content of the Murrah purebreds, Nili-Ravi purebreds, and crossbreeds were in the range $0.66 - 0.79\%$, $0.79 - 0.81\%$, and $0.84 - 0.88\%$, respectively. Therefore, the mineral contents of the milk from three different breeds tested in our study showed slightly higher average mineral contents. This may be due to the differences in animal feeding, period of sample collection during the year, and environmental conditions (Coni *et al.*, 1995).

CONCLUSION

Milk composition varies among the breeds. Milk of the Lanka/local buffalo contains significantly greater quantities of total solids, solid non-fat, and fat contents. Milk protein, lactose, and mineral contents are comparable among Lanka buffalo and crossbreeds of Murrah and Nili-Ravi buffaloes. Based on the greater

total solid, solid non-fat, and fat contents of the milk of the local buffalo, it may be more advantageous compared to the milk of the two crossbreeds in cheese, yoghurt, and curd production, due to higher curd yields.

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