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Physicochemical characteristics of various milk samples available in Pakistan

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Abstract: We report physicochemical characteristics of various kinds of liquid milk commercially available in Pakistan in comparison with those of fresh natural milk from animals. Milk samples were collected from local markets at Peshawar, Pakistan, and analyzed for their physical features, including moisture, total solids, specific gravity, conductivity, viscosity and titratable acidity (lactic acid equivalent), and chemical components and macro-minerals, including total protein, casein, lactose, ash and minerals (Na, K and Mg). These items were compared with the physicochemical characteristics of the fresh natural milk samples from buffalo, cow and goat. The results were also compared with reported nutritional quality of milk from various countries and World Health Organization (WHO) standards. We found that all the physical features and chemical components of commercially available milk in Pakistan markets meet WHO's requirements, except for Na, K, Ca and Mg, which are below the standards.

Key words: Milk, Physicochemical characteristics, Pakistan
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INTRODUCTION

Milk is an important source of all basic nutrients required for mammals including human beings. Milk from various mammals such as cow, buffalo, goat, sheep, camel, etc. is used for different nutritional purposes, e.g., feeding to young ones and preparation of some nutritional products such as milk cream, butter, yogurt, ghee, sour milk, etc. (Webb *et al*., 1974; Hassan, 2005). Nutritionally enriched milk and its products with enhanced biological potential and without health risks are generally demanded (Khan and Zeb, 2007; Baloch *et al*., 2006; Rahman *et al*., 2006).

The major chemical components of milk include water, fats, proteins, carbohydrates, minerals, organic acids, enzymes and vitamins. In order to assess the quality of milk, milk samples including infant formulas, milk powder, milk from markets, raw milk (unprocessed), human milk and animal milk from various countries such as Canada, Poland, Lithuania, Italy, USA, UK and Nigeria have been extensively studied (Coni *et al*., 1995; Dabeka, 1989; Dabeka and McKenzie, 1987; Dobrzañski *et al*., 2005; Hallen *et al*., 1995; Honda *et al*., 2003; Ikem *et al*., 2002; Krelowska-Kulas, 1990; Krelowska-Kulas *et al*., 1999; Ramonaityte, 2001; Rodriguez *et al*., 2000; Simsek *et al*., 2000; Vavilis *et al*., 1997; Vander-Jagt *et al*., 2001).

The contents of 38 micro- and trace elements in raw milk of cows in the Silesian region, Poland, were studied by Dobrzañski *et al*.(2005). They found that the location of cows has a significant impact on the contents of many micro- and trace elements in milk. In another study, infant formula samples sold in Nigeria, UK and USA were analyzed for various essential elements (Ca, Co, Cu, Cr, Fe, Mg, Mn, Mo, Na and Zn) and non-essential elements (Ag, Al, As, Ba, Be, Cd, Hg, Ni, Pb, Sb, Sn, Sr, Ti, Tl, U and V) (Ikem *et al*., 2002). They found that soy-based powder infant formulas generally had higher element levels than milk-based powder formulas. Some

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brands also had low nutritional contents when compared with the recommended dietary allowances (RDAs) and dietary reference intakes (DRIs) for use in North America.

In Pakistan, some of the milk and its products are produced from various indigenous sources, while others are imported. Perveen *et al*.(2005) investigated Na, Cu, Mn and Cr in powder, fresh and processed milk samples available in Karachi city, Pakistan, while Jaffar *et al*.(2004) reported that the levels of 12 metals (Ca, K, Na, Mg, Cu, Fe, Mn, Zn, Cd, Cr, Pb and Ni) in 19 different imported brands of unexpired and expired canned dry milk and the following order of decrease in concentration was observed for both unexpired and expired milk: Ca>Na>K>Mg>Fe>Zn>Cr>Pb>Cu>Ni>Cd>Mn. Hussain *et al*.(2006) determined vitamin C in different processed and unprocessed milk samples marketed in Pakistan. The highest amount of vitamin C was found in powder milk samples followed by liquid packs and the least in animal milk. The effect of temperature and storage time on nutritional quality of ultra-heat treatment (UHT) processed buffalo milk was reported by Rehman and Salaria (2005). They found that the nutritional quality of the milk was adversely affected with the increase in temperature and storage time.

To our knowledge, not many studies on the chemical composition of various kinds of milk marketed in Pakistan have been reported. Therefore, in the present study, we investigated various physical parameters and chemical components of commercially available milk samples, along with their natural analogues. We also compared the findings with the reported data from various regions of the world and with World Health Organization (WHO) standards.

MATERIALS AND METHODS

Reagents and chemicals

Reagents and chemicals of analytical grade and deionized double distilled water were used throughout this work.

Sampling

Two types of milk samples, i.e., commercially available liquid-packed and the fresh natural milk from animals (buffalo, cow and goat), were purchased from local markets in Peshawar, North West Frontier Province (NWFP), Pakistan. The fresh animal milk samples were collected in properly washed and cleaned polyethylene bottles. The bottles were rinsed with milk samples, filled and sealed, in such a way that no air bubbles remained in the bottles. The other milk samples were collected in the same form as marketed. All milk samples were brought to the laboratory for conducting various physicochemical analyses. During the whole sampling processes, its transportation to the laboratory and storage and all precautionary measures were observed.

Physical analysis

The physical characteristics of various milk samples were determined shortly after they were brought to the laboratory. All determinations were carried out according to AOAC (2000)’s methods. Briefly, moisture content was determined by the difference between the known weight of milk sample and the determined weight of the total solid after evaporating the liquid component of the milk sample on a hot plate. The pH measurement was made using a digital pH-meter (HI 8314, Hanna Instruments, Italy) calibrated with pH 4 and 7 buffers. Titratable acidity was measured by titrimetric method, and expressed as percent of lactic acid. Specific gravity, conductivity and viscosity were determined by the standard methods (AOAC, 2000).

Chemical analysis

Nitrogen content (N) in the milk samples was estimated by the Kjeldahl (1983)’s method and crude protein content was calculated as $N\times6.25$, while total casein was determined by its isoelectric precipitation (Plummer, 1988). Lactose content was determined by using Fehling’s solution method (Triebold, 2000). The ash content was obtained by incineration of the sample placed in the muffle furnace at 550 °C for 6 h (AOAC, 2000).

For minerals analysis, the milk solid contents were taken and digested using two volumes of concentrated nitric acid. After adding one volume of perchloric acid, the contents were heated gently on a hot plate followed by a vigorous heating till dryness (approximately 1~2 ml). This digestion technique makes no attempt to dissolve any silicate-based material that may be present in the samples. After cooling, the digested samples were quantitatively transferred to a flask and diluted to 100 ml with deionized double distilled water and then filtered. Atomic absorption spectrophotometer (A. Analyst 700, Perkin Elmer, USA) equipped with standard burner, air-acetylene flame and hollow cathode lamps, as radiation source, was used for the analysis of minerals (Fernandez *et al*., 2002).

Statistical analysis

Results were expressed as mean±*SD* of three separate determinations. The data were statistically analyzed using the statistical program (Origin Version 5.1). The significant differences between means were calculated by a one-way analysis of variance (ANOVA) using Duncan's multiple-range test at $P<0.05$.

RESULTS AND DISCUSSION

Physical characteristics

The physical characteristics such as moisture, total solids, specific gravity, pH, conductivity, viscosity and titratable acidity are important parameters in studying the physicochemical compositions and nutritional aspects of milk. Table 1 shows the various physical parameters of the different milk samples. The moisture contents of milk samples were in the range of (76.4±4.30)% to (86.9±5.12)%. In all tested milk samples, the lowest value was found for the buffalo milk while the highest was for Dairy Queen® milk. Among the animal milk samples, the lowest value was recorded for the buffalo milk, followed by goat milk and the highest was shown by cow milk. For the liquid-packed milk samples, the lowest value was recorded for the Every Day® milk [(80.2±4.10)%] and the highest was for the Dairy Queen® milk [(86.9±5.12)%]. The values for the rest of the milk samples were in between the two. All these values were close to the earlier findings, from 80% to 90% (Webb *et al*., 1974; Hassan, 2005). Water serves as a medium for solution and colloidal suspension for the other components present in milk.

The concentration range of total solids was from (12.9±1.01)% to (15.8±1.53)% as given in Table 1. Goat milk had the lowest amount of total solids [(12.9±1.01)%] followed by cow milk [(13.5±1.22)%] and the highest was found in the buffalo milk [(15.8±1.53)%]. In the liquid-packed milk samples, the lowest concentration of total solids was recorded for the Nestle® milk [(13.7±1.38)%] and the highest was found in Every Day® milk [(15.2±1.39)%]. The total solids in the milk ranged from 10% to 17%, which include fat and non-fat materials. The amount of fat materials is 3% to 4% and the amount of non-fat material is in the range of 7% to 10% (Webb *et al*., 1974; Hassan, 2005). The results show that values for the total solids in all the milk samples are in good agreement with the reported literature.

The specific gravity and pH of all the milk samples were found to be 1.02±0.02 to 1.07±0.08 and 6.59±0.59 to 6.93±0.57, respectively (Table 1). Slight variations were found for the two parameters in all the milk samples. The specific gravity is mainly due to the water contents present in the sample and pH is the parameter that determines the sample acidity and alkalinity. The pH range found in the current study was comparable with the findings in a previous investigation (6.38±0.60 to 6.77±0.88) (Rehman and Salaria, 2005).

The conductivity range of all the milk samples was from (6.55±1.56) ms to (11.0±2.10) mS, as shown in Table 1. In animal milk samples, minimum conductivity was recorded for the buffalo milk

Table 1 Physical characteristics of various milk samples marketed in Pakistan

Milk samples	Moisture (%)	Total solids (%)	Specific gravity	pH	Conductivity (mS)	Viscosity (cP)	Titratable acidity (% lactic acid)
Buffalo	76.4±4.30	15.8±1.53	1.07±0.08	6.93±0.57	6.55±1.56	1.52±0.62	0.90±0.31
Cow	86.8±5.02	13.5±1.22	1.04±0.05	6.76±0.51	9.20±1.95	1.38±0.41	1.44±0.40
Goat	80.5±4.66	12.9±1.01	1.03±0.02	6.59±0.59	10.8±2.07	1.44±0.53	1.35±0.38
Dairy Queen®	86.9±5.12	14.8±1.44	1.03±0.03	6.76±0.53	8.20±1.75	1.69±0.66	1.26±0.35
Every Day®	80.2±4.10	15.2±1.39	1.02±0.02	6.92±0.55	8.70±1.83	1.82±0.75	0.81±0.27
Haleeb®	86.3±4.99	13.7±1.40	1.02±0.03	6.67±0.57	11.0±2.10	1.56±0.39	1.35±0.41
Nestle®	82.3±5.33	13.7±1.38	1.04±0.06	6.82 ±0.58	8.87±1.90	1.49±0.49	1.26±0.39

Each reading is mean±*SD* of triplicate analyses

[(6.55±1.56) mS], followed by the cow milk [(9.20±1.95) mS] and the highest was measured for the goat milk [(10.8±2.07) mS]. Among the liquid-packed milk samples, the lowest conductivity was found for Dairy Queen® milk [(8.20±1.75) mS] and the highest was for the Haleeb® milk [(11.0±2.10) mS]. The conductivity of the milk sample is mainly due to the presence of various electrolytes. The variation in conductivity may be due to the different levels of the electrolytes present in the milk samples.

Similarly, the viscosity ranged between (1.38±0.41) to (1.82±0.75) cP (Table 1). The cow milk had the lowest viscosity [(1.38±0.41) cP], followed by the goat milk [(1.44±0.53) cP] and buffalo milk [(1.52±0.62) cP]. In the liquid-packed milk samples, Nestle® milk had the lowest viscosity [(1.49±0.49) cP] and the Every Day® milk [(1.82±0.75) cP] had the highest viscosity. The values for the titratable acidity were in the range from (0.81±0.27)% to (1.44±0.40)% lactic acid (Table 1). In the animal milk samples, the trend for the titratable acidity is similar to the moisture measurements, i.e., the lowest value for the buffalo milk followed by the goat and cow milk samples. In the various liquid-packed milk samples, the titratable acidity was from (0.81±0.27)% to (1.35±0.41)% lactic acid, respectively for the Every Day® and Haleeb® milk samples. The titratable acidity was found to be little higher than the reported elsewhere [(0.15±0.03)% to (0.26±0.03)% lactic acid] (Rehman and Salaria, 2005).

Chemical components

The milk samples were also subjected to various chemical analyses and the amount of total protein, casein, lactose, ash and mineral elements (Na, K, Ca and Mg) were determined as presented in Table 2. Chemical characteristics of samples showed considerable variations and each sample excelled over other in one or other aspect. The amount of total protein and casein was found to be in the range of (2.59±1.00)% to (4.49±1.39)% and (1.94±0.98)% to (3.77±1.51)%, respectively. Both total protein and casein investigated were within the recommended values, i.e., 2% to 4% for the total protein content and 1% to 3% for the casein content (Webb *et al*., 1974; Hassan, 2005). The results demonstrate that in fresh natural milk, buffalo milk is a rich source of protein and casein while in dairy milk samples, all of them have higher contents of proteins and casein except Haleeb® milk. The milk proteins have the high nutritional value and the principal component of the milk proteins is casein, which constitutes about 75% of all milk proteins (Webb *et al*., 1974; Hassan, 2005). Beside casein, the other milk proteins are lacalbumin, lactglobulin, etc. These results are also comparable with the previous work on the ultra-heat treatment (UHT) processed buffalo milk (Rehman and Salaria, 2005).

In the milk samples, lactose was in the range of (3.49±1.27)% to (5.15±1.59)% and ash content was in the range of (0.40±0.03)% to (1.04±0.13)% (Table 2). Webb *et al*.(1974) and Hassan (2005) reported that the lactose in the milk was from 2% to 5% while ash content was about 0.65%. Lactose is also known as milk sugar and is composed of galactose and glucose. Among all the tested milk samples, the buffalo milk contained the highest amount of lactose. The white ash is mainly composed of oxides and chlorides of mineral elements, which include lime, mangnesia, soda ash, potash, phosphorus oxides, sulfur trioxide, ferric oxide, etc. Similar results were reported previously for the UHT processed buffalo milk (Rehman and Salaria, 2005).

Table 2 Chemical components of various milk samples marketed in Pakistan

Milk samples	Total protein (%)	Casein (%)	Lactose (%)	Ash (%)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)
Buffalo	4.34±1.25	3.26±1.44	5.15±1.59	0.88±0.09	16±1.12	145±10.1	702±88.1	193±18.7
Cow	3.28±1.02	2.46±1.10	4.38±1.36	0.64±0.07	20±1.33	152±11.0	680±79.8	205±22.1
Goat	2.95±0.99	2.18±1.05	4.18±1.40	1.04±0.13	27±1.39	113±8.7	644±76.6	139±15.7
Dairy Queen®	4.48±1.32	3.36±1.40	3.49±1.27	0.78±0.08	55±2.01	128±13.7	823±103.0	160±17.0
Every Day®	4.49±1.39	3.77±1.51	3.57±1.31	0.40±0.03	80±4.49	115±9.3	755±95.7	138±12.5
Haleeb®	2.59±1.00	1.94±0.98	4.21±1.45	0.75±0.06	67±3.56	129±14.5	599±62.1	109±10.1
Nestle®	4.23±1.27	3.17±1.23	4.10±1.33	0.73±0.09	55±2.50	128±12.8	789±101.0	187±18.3

Each reading is mean±*SD* of triplicate analyses

The concentration of Na was in the range of (16±1.12) to (80±4.49) mg/L and the concentration of K was from (113±8.7) to (152±11.0) mg/L (Table 2). In the mammals, concentrations of Na in buffalo, cow and goat milk were found to be (16±1.12), (20±1.33) and (27±1.39) mg/L, respectively. In the dairy milk samples, Diary Queen® [(55±2.01) mg/L] and Nestle® [(55±2.50) mg/L] milk were found to contain the same amount of Na, while Haleeb® and Every Day® milk showed (67±3.56) and (80±4.49) mg/L of Na, respectively. Compared to Na, lower concentration of K was found in goat milk [(113±8.7) mg/L], followed by buffalo [(145±10.1) mg/L] and cow milk [(152±11.0) mg/L]. Similarly, Every Day® milk contained lower amount of K [(115±9.3) mg/L], while in the rest of the liquid-packed milk samples almost the same level of K was recorded. The concentrations of Ca and Mg in all of the milk samples ranged from (599±62.1) to (823±103.0) mg/L and (109±10.1) to (205±22.1) mg/L, respectively (Table 2). The amount of Ca was found to be (644±76.6) mg/L in goat milk followed by cow [(680±79.8) mg/L] and buffalo milk [(702±88.1) mg/L]. Among the commercially available milk samples, lower concentration of Ca was recorded in Haleeb® milk [(599±62.1) mg/L], followed by Every Day® milk [(755±95.7) mg/L], Nestle® milk [(789±101.0) mg/L] and Dairy Queen® milk [(823±103.0) mg/L]. In the case of Mg, its concentration in natural animal milk was (139±15.7), (193±18.7) and (205±22.1) mg/L, respectively for the goat, buffalo and cow milk. Among the liquid-packed milk samples, Haleeb® milk contained (109±10.1) mg/L of Mg, followed by Every Day® milk [(138±12.5) mg/L], Dairy Queen® milk [(160±17.0) mg/L] and Nestle® milk [(187±18.3) mg/L].

The level of mineral elements in the tested milk samples were also compared with the previously reported data from different countries (Jaffar *et al*., 2004; Ikem *et al*., 2002) and with the WHO (1989) recommended values, as shown in Table 3. In the current study, the concentration of Na was found to be much lower compared to the previous studies (Jaffar *et al*., 2004; Ikem *et al*., 2002; Perveen *et al*., 2005) and WHO (1989) standards. In mammals, the level of K (113 to 152 mg/L) found in the present study is comparable to that of the previous work (129 mg/L) (Jaffar *et al*., 2004) while much lower than the WHO value (17200 mg/L) (1989). In dairy milk, the amount of K (15 to 129 mg/L) is found to be lower than that in the reported literature (215 to 221 mg/L) (Jaffar *et al*., 2004) while much lower than the WHO value (3841 to 17000 mg/L). Similarly, the levels of Ca and Mg are also comparable to the previous studies (Jaffar *et al*., 2004; Ikem *et al*., 2002), while lower than the WHO standards (Table 3).

Table 3 Comparison of the metal levels in various milk samples including human

Milk samples	Metal levels (mg/L)			
	Na	K	Ca	Mg
Buffalo[a]	16	145	702	193
Cow[a]	20	152	680	205
Goat[a]	27	113	644	139
Dairy Queen®[a]	55	128	823	160
Every Day®[a]	80	115	755	138
Haleeb®[a]	67	129	599	109
Nestle®[a]	55	128	789	187
Cow[b]	421	129	665	190
Canne unexpired[b]	334	215	842	144
Canne expired[b]	337	221	864	139
Cow[c]	4420	17200	12900	1100
Human[c]	822	3841	2290	257
Nigeria MBPF[d]	169	–	385	26.2
UK MBPF[d]	184	–	344	42.2
UK MBLFFF[d]	332	–	662	60.0
USA MBPF[d]	192	–	398	36.4
USA SBPF[d]	232	–	515	39.2

MBPF: Milk-based powder formulas; MBLFFF: Milk-based liquid first and follow-on formulas; SBPF: Soy-based power formulas; [a]Present study; [b]Jaffar *et al*.(2004); [c]WHO (1989); [d]Ikema *et al*.(2002)

CONCLUSION

In the present study, preliminary investigations were carried out to ascertain the physicochemical characteristics and nutritional quality of various milk samples marketed in Pakistan. The results show that except mineral elements, all parameters of the tested milk samples were within the recommended nutritional levels. These findings may be helpful for the concerned governmental parties to monitor the quality of the milk products in the market of Pakistan. It would be of great interest if further investigations are carried out to examine other organic and inorganic components in the milk in the markets.

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