Profiling and distribution of minerals content in cow, buffalo and goat milk

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Abstract: Nine minerals (calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), phosphorus (P), zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn)) have been estimated in milk of three different species namely, cow (Sahiwal and Tharparkar), buffalo (Murrah) and goat (Alpine x Beetle) of India. Among the species studied, buffalo milk had the highest Ca, P and Mg contents. Na content was found lowest in buffalo milk and K was found significantly higher in goat milk. K was the major mineral in cow and goat milk while Ca was major mineral in buffalo milk. Mineral distribution data indicated that colloidal minerals were highest in buffalo milk followed by goat and cow milk. Ca to P ratio was found maximum in buffalo milk (1.74) and was almost similar in milk (1.45–1.49) of other species studied. Our study indicated that 500 g of milk can meet more than 60% recommended daily allowances of Ca and P as recommended by Institute of Medicine, Washington (DC) and National Institute of Nutrition, Hyderabad.

Keywords: Alpine x Beetle, Minerals, Murrah, Sahiwal, Tharparkar

Introduction

Milk has an important place in human diet. It is almost a complete food for human beings having all the essential nutrients including minerals (De La Fuente et al. 2003). Minerals are important for growth, development and regulation of various vital functions in

our body and approximately 4-6% of human body weight is composed of mineral elements (Saraf & Samant, 2013). These minerals are also important for building strong bones and teeth, and maintaining the ionic equilibrium of body fluids. Even in trace amounts, these minerals perform innumerable vital body functions. Milk contains more than 20 different minerals such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), phosphorus (P), zinc (Zn), iron (Fe), copper (Cu), manganese (Mn) etc. Milk is the most important source of bioavailable Ca and P in our diet, Ca through milk is better retained by the body in comparison to vegetables (De La Fuente et al. 2003). The reported data showed that the mineral contents of the various milk species and breeds varied considerably and their content appeared to be affected by genetic, physical and environmental factors (Raynal-Ljutovac et al. 2008). Although P is an essential nutrient, there is concern that excessive amounts may be detrimental to bone health, especially when accompanied with low Ca intake (Cashman, 2002).

Minerals also play an important role in structure and stability of casein micelles. In milk, most of these macro-elements are distributed differently into diffusible (soluble) and non-diffusible (colloidal) fractions, and the latter form is mainly associated with casein micelles. K, Na and chloride ions are essentially diffusible although Ca, inorganic phosphate and Mg are partly bound to the casein micelles. About one-third of Ca, half of the inorganic phosphate, two-thirds of Mg and over 90% of citrate are in the aqueous phase of bovine milk (Gaucheron, 2005). A small proportion of Ca is also bound to α -lactalbumin as there is one atom of Ca per molecule. Equilibrium exists in the distribution of Ca and phosphate between soluble and colloidal phases. Colloidal Ca phosphate (CCP) plays an integral role in maintaining the integrity of the casein micelle and removal of CCP markedly affects heat stability throughout the pH range 6.6–7.4, but removal of 60–70% of CCP increase stability in the pH range 6.4–7.0 (Gaucheron, 2005). Atomic absorption spectrophotometer (AAS) is commonly used in many analytical laboratories for estimation of minerals in water and in acid digest of sediment or biological materials. The dry or wet ashing method is commonly used to destroy organic material in milk and milk products before analysis by AAS. Fine mist of digested sample solution is aspirated into the flame at a particular wavelength. The decrease in intensity of

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the radiation from the hollow cathode lamp due to absorption by specific atoms in the flame is measured (Wehr & Frank, 2004).

In the past, studies have been done mainly focusing on nutritional status of bovine milk, but lesser data are available for mineral content and their distribution in milk of other species. Also the minerals and their distribution in milk from indigenous breeds was not reported. The various food standard regulation authorities are trying to develop standards for mineral content and their distribution in milk. Our research data will help them to developed new standards. In the present study, nine major and trace minerals (Ca, Mg, P, Na, K, Zn, Fe, Cu and Mn) in milk of three different species namely, cow (Sahiwal and Tharparkar), buffalo (Murrah) and goat (Alpine x Beetle) of India have been estimated along with their distribution in colloidal and soluble phase.

Materials and Methods

Samples and reagents

Fifteen individual milk samples of cow (Sahiwal and Tharparkar breeds), buffalo (Murrah) and goat (Alpine x Beetle) were collected from apparently healthy animals from Livestock Research Center, ICAR-NDRI, Karnal during winter months. All the milk samples were collected fresh and immediately analyzed at National Referral Center for Milk Quality and Safety, ICAR-NDRI, Karnal, India. Water with conductance 0.055 mhos/cm was used for analysis. Nitric acid, hydrochloric acid of analytical grade were procured from Merck KGaA, Dramstadt, Germany. NIST traceable standard solutions for all the elements and lanthanum chloride were purchased from Sigma-Aldrich Inc., St. Louis, USA.

Cleaning of glassware

All the glassware used for AAS analysis were washed properly and soaked in chromic acid solution for 24 h, rinsed with deionized water, dipped in 3% EDTA solution for 24 h and rinsed with deionized water again before use.

Calibration of equipment

The atomic absorption spectrophotometer was calibrated before every analysis and the dilutions of standard solutions were prepared just before analysis. A blank sample and standard solutions of known concentrations were measured for absorbance.

Total ash contents

Ash content of all the samples was determined according to AOAC (2016a) using microprocessor controlled muffle furnace (Metrex Scientific Instruments, New Delhi). Ash was prepared by taking 1 g of milk sample in silica crucible followed by heating on a hot plate to complete charring. The charred samples were

incinerated in a muffle furnace at 550°C for 3–4 h till white ash was obtained. The ash was cooled in desiccators, the weight determined, and ash percentage was calculated.

Fractionation procedure

Fractionation of whole milk between colloidal and soluble phase was done as suggested by Fransson and Lönnnerdal (1983) with modification. The method is depicted in Fig 1. Raw milk samples were defatted by centrifugation (4000 g, 10 min, 4°C) and skim milk was ultrafiltered with Amicon® Ultra-15, 10 KDa Centrifugal Filter Devices (Merck, Germany) using centrifuge (5000 g, 40 min, 25°C). The retentate was discarded and permeate was analyzed for soluble minerals. The minerals present in permeate of skim milk were considered to represent soluble phase of minerals. The original procedure recommended by Fransson and Lönnnerdal (1983) reported the use of ultracentrifugation (150,000 g for 1 h) of skim milk to remove majority of the colloidal phase by pelleting of the casein micelles. The supernatant was further subjected to ultra-filtration using 10 KDa membranes. Gaucheron (2005) also recommended the use of ultra-filtration using 10–15 KDa cut-off membrane to distinguish between colloidal and soluble mineral fraction in milk. As pH and temperature may influence the distribution of minerals in different phases, the experiments in this study were done by avoiding unnecessary delays.

Mineral estimation

Estimation of minerals in whole milk samples and of permeate (obtained after fractionation) was done by dry digestion method. For this, 10 g milk sample or permeate/whole milk was charred in a silica crucible and ashed in microprocessor controlled muffle furnace at 550°C for 5 h. Major mineral elements such as Ca, Mg, Na and K were quantified using method suggested by International Organization for Standardization (ISO, 2007) and trace minerals such as Zn, Fe, Cu and Mn were determined by AOAC (2016b) official method using atomic absorption spectrophotometer (Model: AA-7000; Shimadzu, Japan). Phosphorus was estimated spectrophotometrically; absorbance was noted using Elisa Reader (Infinite 200 Pro Nano Quant) at 820 nm (ISO, 2006). Colloidal mineral content was calculated by subtracting the content of soluble mineral fraction (permeate) from the total mineral content (whole milk).

Statistical analysis

The concentrations of all the elements were reported as the mean $\pm$ S.D. Data obtained were tested by ANOVA (one-way ANOVA randomized complete blocks). Differences and similarities between the means of mineral contents of different species (in whole milk and soluble fraction of milk) were achieved by using the Duncan Multiple Range test. Each mineral element was analyzed at least three times for each animal. Ash content was reported as mean of six determinations.

Fig 1. Fractionation procedure for study of distribution of minerals in colloidal and soluble phase in milk

Fransson and Lönnnerdal (1983)

Results and Discussion

Study of major and trace elements makes it possible to define the degree to which a product can meet the human requirements for particular element. There are several studies dealing with the mineral content of milk, but most of them are of foreign origin.

Total mineral content in milk of various species

The total mineral content in a milk sample is usually assessed by its ash content. The estimated ash content of Tharparkar cow, Sahiwal cow, Murrah buffalo and Goat (Alpine x Beetle) milk was observed to be 0.72 ± 0.003 , 0.74 ± 0.004 , and 0.80 ± 0.002 and $0.76 \pm 0.008\%$, respectively. The ash content was observed significantly high ($p < 0.001$) in buffalo milk as compared to milk of other species. However, the ash content of cow and goat milk did not differ significantly. The average mineral content from various species and its distribution in soluble phase of milk are presented in Table 1. The results indicated that total content of major minerals such as Ca, Mg, and P was found highest in buffalo milk. The content of Ca in buffalo milk was about 1.5 times higher than cow and goat milk. Similarly, Mg content was found 2 times higher in buffalo milk as compared to cow and goat milk. On the other hand, Na content was found lowest in buffalo milk. Potassium content was observed to be highest in goat milk. Among the two species of cow milk, Sahiwal cow milk was

observed to have higher content of Ca, Na, K, P and Zn as compared to Tharparkar cow milk (Fig 2). Table 1 also revealed that among the various minerals studied, K was found as major mineral in cow and goat milk. On the other hand, Ca was found to be as major mineral in buffalo milk. Fe content did not vary in the milk of the species studied.

The total Ca content in Sahiwal cow and Tharparkar cow, buffalo and goat milk was 134.87, 125.43, 204.23 and 135.09 mg/100 g, respectively. Ca content was found to be higher in cow (Sahiwal and Tharparkar breeds), buffalo and goat milk as compared to the previously reported levels such as 104-128; 188, 134.5, mg/100 g, respectively in cow, buffalo and goat milk. (Gaucheron, 2005; Ahmad et al. 2008; Singh et al. 2015). The total Mg content in Sahiwal cow, Tharparkar cow, buffalo and goat milk was observed to be 10.87, 10.24, 23.53 and 10.81 mg/100 g, respectively. The observed Mg content reported in different species showed variation with the reported values given by different researchers. Mg content in bovine milk was in the range 9.7-14.6 mg/100 g (Gaucheron, 2005); while it was 23 mg/100 g in buffalo milk (Ahmad et al. 2008) and 10-21.7 mg/100 g in goat milk (Ruegg, 2017). Total P content observed in Sahiwal and Tharparkar cow, buffalo and goat milk was 90.24, 86.71, 117.45 and 92.06 mg/100 g, respectively. The P content in Sahiwal and Tharparkar cow was observed to be lesser than that (93 - 99 mg/100 g) reported by Gaucheron (2005), whereas higher content (117 mg/100 g) in buffalo milk was

Fig 2. Percentage of soluble major mineral content in milk of various species. Error bars show the variations in terms of standard deviation (n=15)

observed than that (90 mg/100 g) reported by Ahmad et al. (2008). Total K content in Sahiwal and Tharparkar cow was found to be lower (145 mg/100 g) than that (168 mg/100 g) reported by Moreno-Rojas et al. (1994); it was higher in goat milk (174.8 mg/100 g) than reported (135.5 mg/100 g) by Singh et al. (2015). In cow milk, Na content was observed to be lower (around 53 mg/100 g) and was higher in goat milk (52.89 mg/100 g) as reported (44 mg/100 g) by Moreno-Rojas et al. (1994).

Distribution of minerals (colloidal and soluble fractions) in milk of various species

Major minerals

The concentration of major elements present in milk mainly depends on the species, individuality of animal, feed, lactation stage, and health condition of the udder (Cashman, 2006). The major mineral distribution in milk of various species is presented in Table 1. It was noted that Na (> 98%) and K (> 93%) are almost entirely present in soluble fraction of milk of all the species. In general, the contents of soluble minerals were less in buffalo milk and more in cow milk (Table 1 and Fig 1). Maximum fraction of two major minerals i.e. Ca and P was found to be associated with colloidal phase in buffalo and goat milk. More than 60% of P was found to be in colloidal phase in buffalo milk (67%) and goat milk (62%), while in cow milk, major amount (55%) was associated with soluble phase. In case of Mg, the maximum content was

accompanying with colloidal phase in buffalo milk (52%) while in milk of other species it was associated with soluble milk fraction (60-64 %). Higher content of colloidal Ca and P in buffalo milk vis-a-vis other species may be due to inherent high content of casein in buffalo milk; it has been reported by Sindhu and Arora (2011) that except α_{s2} -casein, all other casein fractions are in higher concentration in buffalo milk, which may be responsible for the higher colloidal content of Ca and P in buffalo milk. The soluble fraction of Ca was found higher in milk of Sahiwal (38%) and Tharparkar breeds (35%) than that reported by Gaucheron (2005), in bovine milk (33.5%). The Ca and P (soluble content) in cow milk (38% and 55%) and goat milk (32% and 38%) were observed to have a slight variation with findings of previous researchers. Gaucheron (2005) reported soluble Ca and P content in cow milk was 33.5 and 43% and De La Fuente et al. (1997) indicated 34 and 41%. In present study, in buffalo milk, the distribution of Ca, P and Mg in soluble phase was 22, 33 and 48%, respectively. These findings are in agreement with earlier reported values by Ahmad et al. (2013) (Ca: 22%; P: 32%; and Mg: 50%).

Trace elements

Trace metals are normally needed by living organisms to function properly and are depleted through the expenditure of energy by various metabolic processes of living organisms. Of the total 20 essential minerals, 14 are trace elements (Zamberlin et al. 2012). In the present study, the results indicated that the studied trace

Fig 3. Percentage of soluble trace mineral content (%) in milk of various species. Error bars show the variations in terms of standard deviation (n=15). Sa – Sahiwal, Th – Tharparkar

Table 1. Mineral content (mg/100 g) in milk of various species along with soluble fraction of various minerals

Type of element		Type of milk			
		Cow (Sahiwal)	Cow (Tharparkar)	Buffalo (Murrah)	Goat (AlpinexBeetle)
Calcium	Total	134.87±13.45 ^c	125.43± 8.31 ^d	204.23± 7.98 ^a	135.09± 8.52 ^b
	Soluble	51.16±6.13 ^a (38%)	43.47±4.45 ^c (35%)	44.91 ±4.91 ^b (22%)	43.25 ±5. 33 ^d (32%)
Magnesium	Total	10.87 ± 1.31 ^b	10.24± 1.36 ^d	23.53± 1.33 ^a	10.81± 1.3 ^c
	Soluble	6.99±0.79 ^b (64%)	6.15± 1.14 ^d (60%)	11.33± 0.67 ^a (48%)	6.5± 0.92 ^c (60%)
Sodium	Total	54.06 ± 5.9 ^a	52.95 ±2.42 ^b	42.39± 0.82 ^c	52.89± 2.07 ^b
	Soluble	53.24±5.94 ^a (98%)	52.31±5.94 ^b (99%)	41.47±1.14 ^d (98%)	52.12± 1.9 ^c (98%)
Potassium	Total	144.88 ± 6.09 ^b	142.57± 7.98 ^c	118.05± 7.8 ^d	174.85± 4.85 ^a
	Soluble	141.88±6.31 ^b (98%)	134.92±9.96 ^c (95%)	109.52±6.91 ^d (93%)	167.33±5.67 ^a (96%)
Phosphorus	Total	90.24 ± 1.3 ^c	86.71± 3.75 ^d	117.45±5.26 ^a	92.06± 2.16 ^b
	Soluble	49.31±0.76 ^a (55%)	48.59 ±2.15 ^b (56%)	38.37 ±1. 8 ^a (33%)	34.75 ± 8.65 ^c (38%)
Zinc	Total	0.62 ± 0.14 ^a	0.506 ± 0.066 ^b	0.51± 0.1 ^b	0.48± 0.67 ^c
	Soluble	0.085±0.022 ^a (14%)	0.064±0.01 ^c (13%)	0.06± 0.017 ^c (12%)	0.068 ± 0.015 ^b (14%)
Iron	Total	0.116 ± 0.01 ^a	0.091± 0.02 ^a	0.11± 0.021 ^a	0.078± 0.014 ^a
	Soluble	0.038±0.007 ^a (33%)	0.033±0.005 ^b (36%)	0.027±0.005 ^b (25%)	0.0304±0.0047 ^b (38%)
Copper	Total	0.07± 0.006 ^{ab}	0.071 ± 0.019 ^{ab}	0.061± 0.031 ^b	0.050 ± 0.01 ^c
	Soluble	0.029±0.005 ^b (41%)	0.037±0.005 ^a (52%)	0.021±0.019 ^c (34%)	0.0093±0.001 ^d (18%)
Manganese	Total	0.036± 0.008 ^b	0.06± 0.01 ^a	0.05± 0.018 ^a	0.03± 0.012 ^b
	Soluble	0.0085±0.006 ^b (23%)	0.0088±0.01 ^a (14%)	0.0078±0.014 ^c (15%)	0.0041±0.002 ^d (14%)
Ca/P ratio		1.49	1.45	1.74	1.47

Mean ± SD (n = 15)

Statistical analysis (total milk) by one-way Anova Randomized Complete Block Design using Duncan's multiple Range Test. Data with the same superscript along the same row are not significantly different at $p \leq 0.05$.

minerals (Zn, Fe, Cu and Mn) were associated with colloidal phase in milk of all the species (Fig 3). Among these minerals, Cu was observed to have the highest solubility in cow (41-52%) and buffalo milk (34%). Goat milk was an exception with very low content of Cu in soluble phase (18%). In buffalo milk 75% of Fe was observed to be associated with colloidal phase, while in milk of other species, around 64% of Fe was in colloidal phase. In milk

of all the species, majority of the Zn (>86%) content was observed to be associated with colloidal phase. Copper content was observed higher in goat milk (0.05 mg/100 g) than the previously reported value (<0.025mg/100 g) by Singh et al. (2015), while the Fe content (0.078 mg/100 g) was found lower than that (0.097 mg/100 g) reported by Singh et al. (2015). The soluble fraction of Cu was observed to be lowest in goat milk. The β -casein is the most

Table 2. Contribution to daily dietary intake of minerals by milk of various species (500 g)

Element	RDA values (mg /day) ¹	Cow Milk			Buffalo milk		Goat Milk		
		Mineral Content ² (Sa)	%RDA (Sa)	Mineral Content ² (Th)	% RDA (Th)	Mineral Content ²	% RDA		
Calcium	700-1000 (C)	674	67-96% (C),	627	63-90% (C)	1020	102-145% (C)	665	67%-95% (C)
	67% (M&F),		63% (M&F)		102% (M&F)		67% (M&F)		
	56% (L&P)		52% (L&P)		85% (L&P)		55% (L&P)		
Magnesium	420 (M)	54	13% (M)	51	12% (M)	117.25	28% (M)	54	13%(M)
	320 (F)		17% (F)		16% (F)		37% (F)		17%(F)
	360 (L, P)		15% (L&P)		14%(L&P)		33% (L&P)		15% (L&P)
Sodium	1500 (M, F)	270	18% (M&F),	264	18% (M&F)	210	14% (M&F),	265	18% (M&F)
	370-1200 (C)		22%-73% (C)		22%-71% (C)		18%-57% (C)		22%-71.6% (C)
Potassium	4700 (M, F)	724	15% (M&F),	712	15% (M&F)	590	13% (M&F),	875	18.6% (M&F)
	3000-3800 (C)		19-24%(C)		19-24%(C)		16%-20% (C)		23%29% (C)
Iron	11 (M) 18 (F) 27 (L, P)	0.58	5% (M), 3%(F), 2%(L&P)	0.45	4% (M) 2.6%(F) 1.7%(L&P)	0.55	5% (M) 3% (F) 2% (L&P)	0.4	3.6% (M) 2.2% (F) 1.5% L&P)
Zinc	11 (M) 9 (F) 12 (L, P)	3.1	28% (M) 34% (F) 26% (L&P)	2.5	23% (M), 28% (F) 21% (L&P)	2.6	24% (M) 29% (F), 22% (L&P)	2.4	22% (M) 27% (F) 20% (L&P)
Copper	0.9 (M, F) 1.3 (L, P)	0.35	39% (M&F), 27% (L&P)	0.35	39% (M&F) 27% (L&P)	0.30	34% (M&F), 23% (L&P)	0.25	28% (M&F), 19% (L&P)
Manganese	1.8 (M, F), 2 (L)	0.18	10% (M&F), 9% (L), 7% (P)	0.3	16% (M&F) 15% (L) 11% (P)	0.22	12% (M&F), 11% (L) 8% (P)	0.17	9%(M&F), 8% (L), 6% (P)
	2.6 (P)								
Phosphorus	500 (C)	451	90% (C)	433	87% (C)	585	117% (C),	460	92% (C)
	1000 (M),		45% (M)		43% (M)		58.5%		46 (M)
	700 (F, L, P)		64% (F)		62% (F)		(M), 84% (F)		66% (F)

¹as suggested by Institute of Medicine, 2011 and NIN, 2018; ²content in mg per 500 g milk

C- Children, M-Male, F-Female, L-Lactating & P-Pregnant; Sa - Sahiwal, Th – Tharparkar

abundant protein found in goat micelles; it influences the retention of Cu in the colloidal phase, which causes a decrease in solubility of Cu (Storry et al. 1983). The chemical form of major and trace minerals found in milk or in other foods / supplements is important because it influences the degree of intestinal absorption, utilization, transport, cellular assimilation and conversion into biologically active forms and thus their bioavailability (Cashman, 2006). The distribution study indicated that Sahiwal breed contains highest fraction of soluble major minerals, whereas buffalo milk is characterized by high Ca content in colloidal phase. Thus, the milk products prepared by separation of curd and whey (e.g. cheese, paneer) from buffalo milk will contain more Ca and other colloidal minerals vis-à-vis, such products prepared from cow / goat milk as more minerals are lost in whey fraction (Goyal and Gandhi, 2009).

Contributions to RDA of minerals by milk of various indigenous species per 500 g

Institute of Medicine (2011) has recommended critical values for these elements called Recommended Daily Allowance (RDA). Table 2 depicts the variation in mineral contributions by milk (500 g) of various species. It is worth mentioned here that RDA values for Indians as recommended by National Institute of Nutrition (NIN, 2018) are almost similar as that of recommended by Institute of Medicine, Washington.

Calcium is the most important mineral in milk, which is essential for tissue, bone and teeth development. Adequate intake of Ca is required for maintaining bone health and to reduce risk of osteoporosis. Ca is also known to be anti-carcinogenic (Shin et al. 2002). About 98% of the total Ca present in our body is found in bones and teeth (Latham, 1997). Milk and milk products are known to be very rich source of Ca.

Phosphorus is the second most abundant mineral element found in human body after Ca. About 80% of phosphorus is combined with Ca in bones and teeth whereas 20% participates in body functions like cell growth and contraction of heart muscle (Passmore & Eastwood, 1986). It is also an important component of adenosine triphosphate (ATP), phospholipids and nucleic acids (Peeley, 1998). On comparing contribution to daily dietary intake of minerals by milk of different species, Ca and P contribution to RDA was maximum by buffalo milk. Five hundred grams of buffalo milk is sufficient to meet the daily requirement of RDA of Ca and P for people of all ages including children. The present study indicated highest Ca:P ratio in buffalo milk. As Ca phosphate, P is the most important structural component of bones and teeth but excessive intake of P combined with reduced Ca intake may have negative effects on bones (Cashman, 2002). Higher intake of Ca also decreases absorption of P in the intestine (Nolan & Qunibi, 2003). There must exist an appropriate Ca:P ratio in human diet to ensure optimal bone health. Based on calculation of recommended dietary Ca and P intakes, the optimal dietary Ca:P

ratio (Infants, Children, Adults and Lactating Mothers) varies from 1-2. RDA of Ca:P is 1-1.72 for people of all age groups (Institute of Medicine, 2011). Excessive dietary P intake alone can be deleterious to bone through increased parathyroid hormone (PTH) secretion, and adverse effects on bone increase when dietary intake is low. Low Ca:P ratio affects Ca metabolism and leads to bone loss and osteopenia while high Ca:P ratio is good for bone health. Milk and milk products are rich source of P and Ca as required for adequate Ca:P ratio, and meet the recommended Ca:P ratio (Kemi et al. 2010).

Magnesium is primarily an intercellular mineral. About 50-60% of the total magnesium found in our body is found in bones together with Ca and P (Rude & Gruber, 2004). This mineral element plays diverse roles in protein and carbohydrate metabolism and synthesis of DNA. It forms a complex with ATP (Mg-ATP), which serves as the true substrate for biochemical reactions involving energy utilization (Stryer, 2000). It activates and regulates about 100 enzymes and more than 300 enzymatic reactions in our body. Many of these reactions are directly related to cardiovascular health and help in nerve and muscle function. Mg is required for insulin activity and is therefore important for prevention of type 2 diabetes (Nielsen, 2010). Mg content in 500 g cow milk, goat milk and buffalo milk is 51, 54 and 117 mg, respectively. Buffalo milk can contribute remarkable RDA for Mg especially in children.

Sodium is the main cation involved in the extracellular fluid. This mineral element is known to be associated with regulation of nerve and muscle function, plasma volume regulation and acid-base balance (Anderson et al. 2004). Cow and goat milk contribute maximum towards RDA of Na.

Potassium plays an important role in the regulation of osmotic pressure, blood pressure, acid-base balance, heartbeat regulation and enzyme activation (Yellen, 2002). Milk of all the species contributes substantially to RDA for K in adults and children. But the contribution of goat milk is maximum towards RDA of K.

Zinc is a trace element required in the human body for weight gain and height (Brown & Wuehler, 2000). Zn deficiency causes impaired immune functions and increased propensity to infections (Black, 2003). About 20% of the world population is at risk of inadequate Zn intake (IZINCG, 2004) due to poor bioavailability of Zn from many staple foods. Zn is also an important component of hormone insulin. It is part of more than 200 enzymes involved in digestion, metabolism, protein synthesis, reproduction and wound healing (Salgueiro et al. 2002). Milk and milk products are very important in human nutrition, but an insufficient source of Zn (Cashman, 2006). RDA of Zn was maximum contributed by cow milk followed by buffalo milk.

Iron in the human body plays important part in hematopoiesis, control of infection and cell mediated immunity (Bhaskaram, 2001).

Fe is an important component of hemoglobin in blood, required for oxygen transportation and enzyme systems, vital for formation and functioning of red blood corpuscles and for the functioning of the brain (WHO, 1996). It is essential for several oxidation reactions (Achanta et al. 2007) but unfortunately milk of all the species proved to be poor source of Fe; its contribution to RDA is very low. Contribution of 500 g grams of milk of any of the species to RDA is only between 2-5% for adults.

Copper is the third most abundant trace element found in the human body after Zn and Fe. The total amount of Cu present in an adult is between 80-150 mg (Alla & Abdalla, 2012). This trace element is required for the proper functioning of many enzymes including cytochrome C oxidase for energy production, superoxide dismutase for antioxidant protection, tyrosinase for pigment formation, Lysyl oxidase for collagen and elastin formation and clotting factor v for blood clotting (Sarkar et al. 1994). It is not abundant in milk. In this study, the amount of Cu per 500 g of cow, buffalo and goat milk was found to be 0.34, 0.30 and 0.28 mg, respectively. Cow milk contributes maximum (38%) to RDA of Cu for adults.

Manganese plays significant role in human body by activating certain enzymes such as pyruvate carboxylase, phosphoenol pyruvate carboxykinase glycosyl transferase and the mitochondrial superoxide dismutase (Keen et al. 2004). It also plays an important role in reproductive hormone production, urea excretion and immunity (WHO, 1996). Mn is contributed to a higher extent by buffalo milk as compared to milk of other species.

Conclusions

Assured information regarding mineral element concentration in milk is essential for society from nutritional and technological point of view. In this study, different concentrations of mineral elements in total as well as the soluble fraction of milk were determined. Out of all the milk samples, buffalo (Murrah) milk provides highest mineral content except K which is highest in goat milk. This confirms that buffalo milk is the richest source of essential minerals in comparison to milk of other species. Cow milk showed a maximum soluble fraction of essential minerals necessary for the body. Marked increase in levels of soluble mineral content in cow milk could favor the absorption of these minerals in gastrointestinal tract. Results obtained in the present study demonstrate the positive contribution of the mineral elements present in milk of different species to RDA, especially from buffalo milk.

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