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Status of Major and Trace Minerals in Milk: A Review

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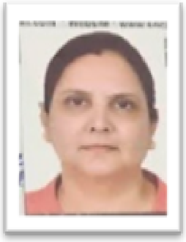

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Abstract

Milk is a full diet containing all food nutrients, including minerals.Minerals are vital components for maintaining good health of bones and teeth and also, for preserving the body's fluid ionic balance. These minerals conduct many essential body roles even in trace quantities, such as acting as catalysts, activators of physiological functions. Deficiency of minerals in the body causes health issues such as stunted growth, skin rashes, hair loss, weakness, mobility disorder, lack of balance, susceptibility to illness, anemia, diarrhea, hormone imbalance, low and high blood pressure, hypocalcemia, osteomalacia, nausea, vomiting, headache, premature ageing, etc. A number of minerals are required by the human body to perform certain metabolic functions.

Keywords: Milk, Ionic, Balance, Catalysts, Activators,Minerals.

Introduction

All the twenty minerals (Ca, Na, P, K, Cl, Mg, Zn, Fe, Cu,Mn, Mo, Si, As, F, Ni, Se, Co, Cu, I and B) found important in the human diet are present in milk(Flynn 1992). In diet, calcium and phosphorus found in milk are of considerable significance. For healthy bones and teeth, the proper ratio of calcium and phosphorus in the diet is crucial; each of these nutrients help avoid hypertension, lessen the risks of developing colon/breast cancer, boost weight management, and decrease the likelihood of developing kidney stones. The durability of proteins and their nutritional and organoleptic qualities are the role of minerals in milk and milk products. Minerals, based on their composition, are dispersed differently in the aqueous and micellar stages of milk. A complex balance between the diffusible / soluble and non- diffusible/ colloidal phases occurs. Chloride, potassium and sodium are basically found in the soluble (diffusible) phase, and phosphorus, magnesium and calcium are partially bound to casein micelles. Physico-chemically, it is important to research the chemical form in which mineral elements are found in milk, as this form (soluble / colloidal) is responsible for the absorption and bio-use of minerals in the gastrointestinal tract.Minerals constitute a small portion of milk, but play a major role in casein micelles formation and stability.

The mineral fraction can be categorized as per body requirements (per day) in two categories viz.; major minerals (>50 mg / day) and minor minerals (<50 mg / day). There is another set of minerals that are required in trace amounts, thus referred to as“Trace elements”. These include zinc, iron, copper, molybdenum, manganese, etc.

The milk's ash composition is its mineral content. The major minerals that exist in the milk are: Phosphorus, magnesium, sodium, potassium, chlorides, calcium and iron, copper, zinc, manganese. Compositionally, Buffalo milk is among the richest, with higher levels of calories, total solids, proteins, caseins, lactose and ash than sheep, cedar, camel and human milk (Salman et al., 2014).

During mastitis, mineral content in milk is often altered, especially to highly elevated levels of sodium and chloride ions. Owing to its high calcium content, the poor heat stability of buffalo milk. Via partial substitution of calcium with sodium and potassium, the heat stability of milk can be increased.

For each mineral, the distribution of large milk minerals into soluble and colloidal fractions is distinct (diffusible and non-diffusible). Highly soluble are sodium, potassium and chloride ions, while Mg, Pi and Ca are partially bound to the casein micelles. Half of inorganic phosphate, two thirds of magnesium,more than 90% of citrate and one third of calcium are present in the soluble phases of milk. Small part of calcium is also bound to α-lactalbumin (for one protein molecule there is one atom of calcium). Major minerals are not bound to fat globules and lactose.

The distribution of P and Ca into colloidal and soluble phases varies considerably with the animal. In general, milk containing a high level of calcium or phosphorus (sheep or buffalo milk) often contains a high level of these minerals in the colloidal process.

Aim of the study

As major and trace minerals like Ca, Mg, Na, K ,P, Zn, Cu and Mn play vital roles in maintaining the proper balance of water in the human body, and are also important for bone and teeth health. All of them are present in milk. The present study will be very useful in providing information regarding the importance of major and trace minerals.

EssentialMinerals Present in milk

Calcium (Ca)

It isone of the major minerals found in milk. In cow's milk, it is about 120 mg /100ml. About 99% of Ca is found in skim milk, where it is dispersed between the colloidal and aqueous phases. In colloidal phase Ca is around 67% whereas in aqueous phase 33%. Calcium in ionic form is free in the soluble / aqueous fraction to form the related salts with Pi and citrate.

The aqueous/ soluble fraction is saturated with calcium phosphate. The clusters of Ca and P form granules called nanoclusters in the casein micelles. The diameter of these mineral structures is equivalent to 3 nm. Controlled by the physio-chemical properties of milk like pH, the calcium and inorganic phosphate present in one stage will be passed into another stage. In these two stages, the result of these changes maintains "milk mineral equilibrium." Biological acidification (lactose fermentation in lactic acid) is one of the most significant transformations widely carried out. During this, calcium gets solubilized and passed to the soluble fraction of acidified milk (Gaucheron, 2011). The aqueous fraction is omitted in some cases, and some milk products, like processed cheeses, have varying amounts of calcium. This mineral plays an important part in changing various functional characteristics of milk products. Calcium exists inthreeforms in milk- insoluble calcium i.e. CCP, soluble calcium and free calcium in ionic form. The concentrations of these three forms in millimoles are 20, 10 and 1.5 mm respectively.

Phosphorus (P)

Phosphorus is an essential part of milk and dairy products. It helps preserve acid-base equilibrium, cell membrane composition, and protein-energy metabolism. In milk, total phosphorus is around 95 mg/ 100ml. Since phosphorus occurs in various forms in milk, the chemical definition is very complicated and different forms of phosphorus occur. Schematically, phosphorus is present in organic (Po) and inorganic phosphates (Pi). Organic phosphorus is bound to organic molecules such as nucleosides, casein molecules, RNA, DNA, sugar phosphates, phospholipids and nucleotides. Ionization of Pi takes place depending on pH. Po is mostly related to casein molecules in milk, which are in the micellar phase. The aqueous phase includes the other types of organic phosphorus like sugar phosphates, nucleotides, nucleosides, phospholipids, RNA and DNA. Pi is divided into the aqueous and the micellar phase, responsible for milk's mineral balance. Pi is 50 percent in the soluble phase and 50 percent in the micellar phase at pH 6.7 to form Calcium Phosphate nanoclusters. Inorganic P can be transferred to the aqueous process during the transformation of milk into milk products, especially during the calcium acidification in cheese making when the whey is extracted, it may be lost. This explains the existence of varying phosphorus levels determined for different milk products. During the process of melting in processed cheeses, salts corresponding to polyphosphates produce large quantities of phosphorus.

Ca / P

Calcium and phosphorus are the main bones that make up minerals such as calcium phosphate. Phosphorus is the most essential structural part of bones and teeth, but high phosphorus consumption combined with decreased calcium intake may have detrimental effects on bones (Cashman, 2006). Reasonable Ca: P ratio in human diets must occur to ensure optimum bone protection. Excessive dietary phosphorus consumption alone can be detrimental to bone by increased release of parathyroid hormone (PTH) and adverse effects on bone development when dietary intake is minimal.

Magnesium (Mg)

It stimulates some 100 enzymes and Mg controls more than 300 enzyme reactions in our body. Magnesium is not plentiful in milk and milk products relative to calcium. Its content in milk is approximately 12 mg/ 100ml. Magnesium is divided into the micellar (5 mg/ 100ml) and the soluble fractions (7 mg/ 100ml) in milk. Magnesium is aligned with citrate and inorganic phosphate in the soluble fraction and as nanocluster in the casein micelles. The management of these distributions depends on physicochemical conditions particularly acidic pH. Magnesium in the micellar phase gets soluble into aqueous fraction during the milk acidification. Magnesium amounts differ in various milk products depending on processing treatments / methods. Although the Mg concentration is comparatively low in milk and its products,still these can be treated as sources for Mg ion (100 ml milk yields 11 mg, comprising approximately 15-16% of human RDA) (Gaucheron, 2011).

Sodium, Potassium and Chloride (Na, K and Cl)

Such monovalent ions are primarily found in the soluble fraction of milk and its products, where these are correlated freely with oppositely charged ions. NaCl levels are improved in dairy products by salting or salting (cheeses). NaCl leads to curd drainage, the organoleptic qualities of different cheeses,enzyme's selection and microorganisms during the period of ripening. Different types of cheese have varied concentrations of NaCl. Sodium ions hold the equilibrium between water and acid-base. Potassium has an important part in nerve conduction.

Iron (Fe)

It is an important part of hemoglobin and is important for a variety of oxidation reactions. Fe is roughly 0.05 mg/100ml in cow milk. There are two ionization states (+2 and +3) available. In cow's skim milk contains iron, mainly attached to casein fraction, inorganic P, whey protein, citrate and lactoferrin.Concentration of $\mathbf{L_f}$in human and cow milk is 1000mg/L and 100 mg / respectively (Cashman,2002). Milk and its products are known to be poor iron sources with limited contribution to the overall iron consumption. The content of iron in milk is low and is influenced by the presence of lactoferrin, an iron binding protein and Xanthine oxidase, which generates reactive oxygen species(Wabel, 2008). 200 ml of milk provides only 0.1 mg of iron (about 2-3 percent of the RDA).

Copper (Cu)

Like iron, milk and its products are not a rich source ofCu. The content of copper in bovine milk is around 0.01 mg/100ml, around 2% with fats, 8% attached to whey proteins, 47% inorganic phosphate and citrate ions (low molecular-weight) 44% to casein. This variance may be due to the various sample processing procedures and analytical approaches used for assessing the sample (Gooneratne et al., 1989). Milk and its products contribute only 5% of RDA (Lonnerdal, 1997, Wabel, 2008).

Zinc (Zn)

It aids digestion, metabolism, reproduction and wound healing. Zinc 's content in milk between 0.3 -0.4 mg / 100ml. In cow's milk, maximum Zn is in skim milk (around 99 percent) and potentially in contact with Pi and Pi of casein micelles. About 95 percent of zinc is attached to casein micelles. In aqueous phases, a small component is connected to citrate molecules. Milk and its derivatives greatly add to the supply of zinc (100ml of milk provides 0.4 mg contributes to 20 percent of the RDA). Zinc is bound to approximately 95% with the casein micelles, which is why the soluble zinc content is lower among all animals (Fuente et al., 1997). Zinc is almost entirely linked to high molecular compounds in cow's milk (Lonnerdal, 1997).

Manganese (Mn)

There is very little research on the manganese concentration in milk of various animals. The fat globule membrane is considered to be partially present in manganese. Lactose synthase is a manganese-dependent enzyme found in milk. The production of oxidized flavor in bovine milk is reduced by adding manganese bind some salts to which Fe and Cu bind, their displacement by manganese leads to reduction of fat oxidation (Lonnerdal et al., 1981).

Selenium (Se)

It is found in milk and milk products. This metalloid has Sulphur-like properties and is sometimes described as synonymous with antioxidant glutathione peroxidase. It has 30µg/l milk concentrations. Selenium is primarily present in skim milk, where casein and whey proteins are associated but not present in milk fat. While this element's concentration is not well known in other dairy products, milk is an essential selenium supplier (300 ml of milk supplies 10µg of selenium).The contribution of milk and its products to daily intake of Se is evaluated between 8% and 39% of RDA in different countries (Foster, 1998).

Absorption/ Bioavailability of minerals present in milk

A variety of compounds that are found in food affect the use of minerals. Vitamin D, lactose and acidity are believed to increase calcium absorption in the intestine. Fiber Like cellulose and hemicellulose and acids like phytic acid; oxalic acid, saturated long-chain fatty acids and uronic acid form insoluble calcium and calcium absorption complexes (Allen, 1986). The availability of calcium in milk products is influenced by the presence of calcium complexes (Kansal, 2002).

Bioavailability can be affected by the chemical form of microelements; free forms such as ions in soluble form are well absorbed, whereas bounded forms are poorly absorbed (de la Fuente et al., 1997). Due to their capacity to bind and retain Ca in a soluble state in the lumen of the intestine, and thus usable for absorption, casein phosphatides produced during casein digestion have a beneficial effect on Ca absorption. During the fermentation of milk into yoghurt, noticeable changes in the amounts of non-sedimentable minerals favor the absorption of certain minerals (Ca, Mg, P, and Zn) in the gastrointestinal tract (de la Fuente et al.,2003).

Both macro and micronutrients are best consumed in the acidic atmosphere of the stomach as they are found as salts, which are relatively easy to solubilize: carbonates, sulphates, oxides. Compared to inorganic salts prescribed to animals as mineral supplements (blends, premixes) used in the compound feed, the mineral substances of vegetable feed have a lower assimilation coefficient i.e. lower absorption.

The main sources of calcium are milk and milk products (cheese, yoghurt etc.). Most of the dietary calcium (70%) comes from milk and milk products, as casein micelles are a normal calcium carrier. The average absorption of calcium from cow's milk/cheese/yoghurt ranges between 21-45%. The absorption of calcium depends on a person's vitamin D level and age. It has also been shown that lactose also inhibits the absorption of calcium in the intestine. The bioavailability of calcium compounds is higher in milk and milk than in other forms, such as fruits and vegetables. This can be due to the presence of calcium in strongly phosphorylated casein fragments, known as casein phosphopeptides (CPPs). These peptides exist primarily when milk products, such as cheese or yoghurt, are processed under the action of milk endogenous, milk coagulating and/or microbial enzymes on caseins (Dupas et al., 2009). The ability to form CPP-metal ion complexes is a remarkable characteristic of CPPs, which will theoretically improve the bioavailability of calcium and iron, likely by retaining metals soluble in the distal small intestine (Peres et al., 1999; Dupas et al.,2009). Proteins also promote the absorption of calcium, and phosphopeptides derived from casein enzymatic hydrolysis (caseinophosphopeptides) can form soluble calcium complexes. The phosphopeptides present in the gut are important because calcium precipitates owing to the phosphates found in the intestinal tract(Lee et al., 1983).

Without drinking milk and milk products, the RDA for calcium is hard to achieve. Special focus should have been given to the bioavailability of milk calcium.Bovine milk's average calcium absorption ranges from 21 percent to 45 percent. The bioavailability of cheese and yoghurt calcium is almost equivalent to that of milk (Zamberlin et al., 2012).

Absorption of iron from bovine milk by babies was also tested using isotopes of slightly lower absorption (10 percent) (Mc Millan et al., 1977). Infant formulations fortified with high doses of iron (12 mg/ l/l) consume just 3-4 percent of iron. No explanation is available for the extremely high bioavailability of iron in human milk. Iron bioavailability in human milk varies between 49-70%, which is substantially higher than bovine milk (10-34%). There is no simple solution to this variance. But this may be due to the elevated levels in human milk of lactoferrin (the glycoprotein that binds iron ions). Another explanation may be the presence in human milk, a high lactose and ascorbate content that promote the absorption of iron. It might be due to the high level of lactoferrin (glycoprotein that binds iron ions) present in human milk. Another reason may be the presence of high levels of lactose and ascorbate in human milk, which facilitates iron absorption.

In human milk, the bioavailability of zinc is far higher than in cow's milk since it is attached to low molecular mass ligands (such as citrate) in human milk, which promotes absorption. In cow milk, zinc binding to casein is 10 times higher than in human milk, it can block zinc formed in the abdomen inside casein curd, rendering it inaccessible for absorption (Pabon and Lonnerdal,2000).

Little research on copper absorption in the human body is available. Experiments conducted on rats showed 83% human milk absorption, 76% cow milk absorption, and 86-87% dairy baby formula (Cashman, 2002). In the presence of soluble carbohydrates and proteins, organic acids and low molecular weight chelates, Cu absorption and bioavailability is improved by increasing its solubility (Wapnir, 1998). The intake of manganese from human milk is 8.2 percent and slightly greater than that of cow's milk (2.4 percent).

Conclusion

Minerals perform many important roles in the body, including the action of enzymes, the development of bones and the transport of oxygen. Milk is an excellent source of minerals especially phosphorus, magnesium, calcium, potassium, zinc and selenium. Milk contains small quantities of copper, iron, sodium, and manganese and is not known to be a significant dietary source of these minerals.Temperature variation causes flow of calcium phosphate into and out of the casein micelle.

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