Pakistan Journal of Nutrition 5 (3): 198-202, 2006
ISSN 1680-5194
© Asian Network for Scientific Information, 2006

Major and Trace Element Levels in Powdered Milk

E.O. Akpanyung
Department of Biochemistry, Faculty of Basic Medical Sciences, University of Uyo, Uyo, Nigeria

Abstract: Six commercial brands of powdered milk produced in Nigeria were analyzed for their major and trace element composition. The products were found to be good sources of mineral nutrients except for sodium. This paper suggests the need for regular intake of this brand of processed milk so as to derive optimal benefits from its reservoir of major and trace elements.

Key words: Food fortification, major/trace elements, powdered milk, recommended dietary allowance (RDA)

Introduction

Milk has been defined as an emulsion of fat globules in a suspension of casein micelles (composed of casein, calcium and phosphorus) all suspended in an aqueous phase which contains solubilized lactose, whey proteins and mineral salts (Jensen, 1998). It is the natural secretion of the mammary glands, which plays a fundamental role in nutrition, growth, development and immunity (Woo *et al.*, 1995). The milk of each mammalian species is unique in composition and nutritional value (Kataoka *et al.*, 1991).

Cow's milk and milk products have played an important role in human nutrition. Fresh cow milk is reported to contain about 88% water (Kataoka *et al.*, 1991). During processing, the water content of the milk is reduced. The concentrated milk products such as evaporated milk are obtained by partial elimination of water whereas the dried milk products are generated when the water content has been reduced to less than 4%. The reduction in water content confers desirable qualities on the milk such as increased shelf life, product flexibility and decreased transportation cost (Miller *et al.,* 1999).

Many brands of dried instant cow milk are produced and marketed in Nigeria by various Dairy Food Companies. Examples of such products include: Peak, Carnco, Miksi, Milcow, Cowbell, Blue boat, and Three Crown brands. These products are available in a wide range of packets to meet the needs of low and high income earners. Additionally, the relevant companies have embarked on advertisement campaigns concerning the nutritional quality of their products. In many cases, the manufacturers of these instant milk powders advocate their products as having been fortified with several mineral elements. However, the actual composition of individual mineral element is often not indicated on the product labels of these milk powder.

The mineral elements constitute an important group of nutrients required by the human body for optimal functions (WHO, 1996). They can be divided into macro minerals (major elements) and micro minerals (trace elements). The macro minerals such as sodium, potassium, magnesium, calcium and phosphorus are required by the body in amounts greater than 100mg per day whereas the micro minerals such as iron, copper, zinc and manganese are required in amounts less than 100mg per day (Murray *et al.,* 2000).

The present study was carried out to assess the levels of some macro and micro elements in powdered milk produced in Nigeria in order to bring to focus the contribution of these dairy products to the mineral intake of consumers. The importance of this study becomes evident when considered against the claims by manufacturers that the mineral element content of their products have been considerably enhanced.

Materials and Methods

Six different brand of instant powdered milk, coded A - F were analyzed. Three samples (sachets) of each brand of powdered milk were purchased from various supermarkets here in Uyo, Akwa Ibom State, Nigeria. The samples were stored in airtight containers at ambient temperature until the completion of analyses.

Ash content was determined using the standard method of AOAC (1984). For mineral element analyses, the ash obtained from one gram of each powdered milk sample was leached with 5ml of 6M HCl and the volume made up to 20ml. The resulting solution was used in mineral element determination. Sodium and potassium were determined by flame photometry (Jenway PF7 Flame Photometer, Essex, UK). Phosphorus was determined by the Molybdovanadate Colourimetric method (Vogel, 1969). Other mineral elements were determined using an atomic absorption spectrophotometer (Unicam Analytical System, Model 919, Cambridge, UK). Sets of standards were prepared for each element using AAS stock solution, and calibration curves were prepared. The mineral element concentration in each powdered milk sample was deduced from the calibration curves.

Results and Discussion

The ash and mineral element composition of the powdered milk samples are summarized in Table 1.

Table 1: Ash(%) and Mineral Element Composition of Powdered Milk (mg/100g)*

Sample Code	Ash	Na	K	Ca	Mg	P	Fe	Cu	Zn	Mn
A	5.74±0.02	7.54±0.12	1710±32	1110±2.00	110±0.08	690±3.20	9.94±0.24	0.75±0.06	8.40±0.10	0.60±0.12
B	5.49±0.01	7.76±0.14	1750±39	1090±2.20	100±0.11	640±5.00	9.02±0.06	0.60±0.02	22.50±0.10	0.99±0.08
C	5.67±0.04	7.60±0.20	1720±37	1150±1.80	100±0.06	680±8.00	11.82±0.22	1.02±0.08	8.15±0.13	0.67±0.03
D	5.81±0.02	11.92±0.60	1700±20	1080±2.50	100±0.10	690±3.40	10.39±0.03	1.06±0.08	7.47±0.14	0.86±0.05
E	5.10±0.03	6.99±0.41	1500±26	1120±3.00	110±0.08	610±4.12	10.04±0.05	1.51±0.07	7.76±0.11	0.76±0.13
F	4.95±0.02	2.92±0.11	1680±35	1115±2.20	100±0.10	650±4.70	10.74±0.20	0.85±0.02	21.38±0.16	0.90±0.10

* Values represent the mean of triplicate determinations ± SD for each sample.

Individuals in Nigeria do not consume 100g of powdered milk at any particular instant. Rather about two teaspoonfuls of milk (approximately 10g) are added to a cup of beverage before drinking. Aside from this, the same measure of available brands of powdered milk is often consumed in a meal of local starchy staple called 'Ogi' (Muller, 1970). It may also be consumed mixed in a meal of custard powder (Akpanyung *et al.,* 2001). Thus, the mineral element composition per 10g of the powdered milk samples is shown in Table 2.

The ash content of the powdered milk samples was found to range between 4.95 and 5.81%. These values were found to be similar to the reported values for ash on the product labels (5.50 – 6.00%). The ash content of a food sample is a reflection of its mineral element composition. Kataoka *et al*. (1991) reported the ash content of fresh cow milk to be 0.72%. Fresh cow milk is not classified as a rich source of mineral elements except for Ca and P, hence the need to enhance the mineral composition by fortification (Jensen, 1998).

Sodium is the principal cation in the extracellular fluid. The element is known to be involved in nerve and muscle function, regulation of plasma volume and acid – base balance (Berne and Levy, 1998). Zololor (1997) reported that the actual nutritional requirement for sodium is about 1g per day but that the average intake of this element per day is about 5g. Continuous over consumption of sodium has been found to hasten the onset of hypertension and to worsen an already existing hypertensive condition (Topian, 1979) hence the need to limit sodium intake. Table 1 shows that powdered milk is a poor source of sodium. The element was found to be quite low in sample F with a value of 2.92± 0.11mg/100g.

Potassium is the major cation in the intracellular fluid. Davis and Knox (1970) reported that the correct balance between potassium in the intracellular fluid and sodium in the extracellular fluid is essential for life. Nerve impulses are transmitted by electrical currents associated with momentary exchange of potassium and sodium ions (Stryer, 2000). There is also evidence that this element plays a role in the regulation of osmotic pressure, blood pressure and acid-base balance (Davis, 1970; Yellen, 2002). Potassium is also an enzyme activator (Suelter, 1970). The estimated safe and adequate daily dietary intake for potassium (FNB 1989) is 550 – 4575mg in children and 1875 – 5625mg in adults. Table 2 shows that powdered milk contributes substantially to the daily requirements for potassium in adults and children.

Calcium is important in the development and maintenance of strong bones and teeth. It is also involved in nerve function, muscle contraction and blood clotting (Passmore and Eastwood, 1986). Most of the calcium in the human body (about 98%) is found in the bones and teeth (Latham, 1997). Milk is known to be a very rich source for calcium. Gerrior *et al.* (1998) reported that milk and milk products supply about 73% of the calcium in the American diet. The RDA for calcium (FNB, 1989) is 800mg for children aged 1-10 yrs and 800-1200mg for adults. Table 2 shows that 10g of the powdered milk samples provide 108-115mg of Ca. i.e. 13.5-14.4% of the RDA for calcium in children and 9.0-9.5% of the recommended intake for adults.

Phosphorus is ranked as the second most abundant mineral element in the human body after calcium. About 80% of the phosphorus is combined with calcium in bones and teeth whereas the other 20% participate in body functions such as cell growth and contraction of the heart muscle (Passmore and Eastwood, 1986). The element is also an important component of adenosine tri-phosphate, phospholipids and nucleic acids (Peeley, 1998). Jensen (1998) reported that phosphorus together with calcium are mainly associated with the micelle structure of milk. Fresh cow milk has been found to contain 93mg of phosphorus per 100g (Kataoka *et al*., 1991). The present study indicates that the powdered milk samples contain 610-690mg of phosphorus per 100g (Table 1). This amount of phosphorus is high when compared to the level of this element in fresh cow milk (Kataoka *et al.,* 1991). Apparently, the powdered milk samples have been substantially fortified with phosphorus. At the level in which the powdered milk is usually consumed by Nigerians (Table 2), 61-69mg of phosphorus could be obtained from this source. Hence, the percentage contribution of powdered milk to the RDA for phosphorus in children is estimated to be 7.6-8.6%.

Magnesium is primarily an intracellular nutrient. About 50-60% of all magnesium in the body is found in bones together with calcium and phosphorus (Passmore and Eastwood, 1986). The element plays diverse roles in protein and carbohydrate metabolism, synthesis of DNA as well as muscle relaxation. Furthermore, magnesium forms a complex with ATP (Mg - ATP) which serves as

Table 2: Mineral Element Composition of Powdered Milk (mg/10g)*

Sample Code	Na	K	Ca	Mg	P	Fe	Cu	Zn	Mn
A	0.75	171	111	11	69	0.99	0.075	0.84	0.06
B	0.78	175	109	10	64	0.90	0.06	2.25	0.09
C	0.76	172	115	10	68	1.18	0.10	0.82	0.06
D	1.19	170	108	10	69	1.04	0.11	0.75	0.08
E	0.70	150	112	11	61	1.00	0.15	0.78	0.07
F	0.29	168	115	10	65	1.07	0.09	2.14	0.09

* Values are based on the amount of powdered milk in two teaspoons.

the true substrate for biochemical reactions involving energy utilization (Stryer, 2000). Kataoka *et al.* (1991) reported that fresh cow milk contains 13mg of magnesium per 100g of milk. In the present study it was found that 10g of the powdered milk samples contain 10 –11mg of magnesium (Table 2). This is a remarkable contribution to the RDA for magnesium, which is 70-170mg for children and 270-400mg for adults (FNB, 1989).

Blum (1996) reported that iron is the fourth most abundant element in the earth's crust. In the human body, iron is known to play important role in haematopoiesis, control of infection and cell meditated immunity (Beard, 2001; Bhaskaram, 2001). Despite its physiological importance, the problem of iron deficiency still persists affecting an estimated 2000 million persons worldwide (Trowbridge and Martorell, 2002). According to MacPhail and Bothwell (1992), up to half of all anaemia is caused by dietary iron deficiency. The consequences of iron deficiency include reduced work capacity and poor intellectual performance (Maziya-Dixon *et al.,* 2004). Adolescent girls, women of childbearing age and pre-school age children are most vulnerable to iron deficiency (Maziya-Dixon *et al.*, 2004). Efforts to combat iron deficiency includes the widespread fortification of foods with iron (Blum, 1997). The powdered milk samples analyzed in this study were found to contain 9.02-11.82mg of iron per 100g (Table 1). A 10g portion of these milk powders (Table 2) contain 0.90-11.8mg of iron contributing 9.0-11.8% of the RDA for iron in children and 6.0-9.0% of the RDA for iron in adults. Kataoka *et al*. (1991) reported that fresh cow milk contains 0.05mg of iron per 100g. Thus, the instant milk powders contain significant amounts of iron.

Zinc is a trace element required for weight gain and height (Brown and Wuehler, 2002). Low plasma Zinc has been associated with impaired immune functions and increased propensity to infections (Black, 2003). Unfortunately, about 20% of the world population is reported to be at risk of inadequate zinc intake (IZiNCG, 2004). The reasons advanced for this include inadequate intake as well as the poor bioavailability of zinc from many staple foods. Currently, there is strong advocacy for the inclusion of zinc in the list of priority nutrients for food fortification (Bowley, 2005). The RDA for zinc (FNB, 1989) is 10mg for children and 12-15mg for adults. Table 1 shows the level of zinc in powdered milk to be in the range of 7.74-22.50mg per 100g. Samples B and F were found to contain about three times the amount of zinc present in the other milk samples. Thus, powdered milk can be considered to be a rich source of zinc.

Copper is the third most abundant essential trace element in the body after iron and zinc (Sarkar, 1994). The total amount of copper in the body of adults is 80 - 150mg (Kruse-Jarres, 1994). This element is essential for the proper functioning of many enzymes including cytochrome C oxidase (energy production), superoxide dismutase (antioxidant protection), tyrosinase (pigment formation), dopamine hydroxylase (catecholamine production), lysyl oxidase (collagen and elastin formation), clotting factor V (blood clotting) and ceruloplasmin (antioxidant protection, iron metabolism and copper transport) (Sarkar, 1994). A daily intake of 1.5-3.0mg of copper is recommended for adults whereas in children, the recommendation is 0.7-2.0mg (FNB, 1989). Unfortunately, the average copper intake has been shown to be well below the recommended allowances with intakes of less than one milligram being very common (Burch and Hahn, 1983). In the present study, the amount of copper in powdered milk was found to range from 0.60 to 1.51mg per 100g (Table 1). The level of copper in samples C, D and E was especially high. Table 2 shows that a 10g portion of the milk samples contain 0.06-0.15mg of copper contributing 4-10% of the RDA for copper in adults and 8.5-21.4% of the RDA for copper in children. Kataoka *et al.* (1991) reported the copper content of fresh cow milk to be 0.011mg/100g. Burch and Hahn (1983) had earlier observed that milk and dairy products are poor sources of copper. The present study, however, shows that powdered milk is rich in copper and contributes substantially to the recommended daily intake for adults and children.

The body of an adult is reported to contain 10-20mg of manganese (Kruse-Jarres, 1994). This element plays an important role in the human body by virtue of the wide diversity of enzymes that require it for activity. Notable examples of such enzymes include pyruvate carboxylase, phosphoenol pyruvate carboxykinase, glycosyl transferase, xylosyl transferase and the mitochondrial superoxide dismutase (Baly *et al.,* 1985; Malecki and Greger, 1985; Hurley and Keen, 1989). The estimated safe and adequate daily dietary intake for manganese is 1-2mg in children and 2-5mg in adults (FNB, 1989). Davis and Greger (1992) reported that women who constantly ingest less than the estimated safe and adequate daily dietary intake for manganese exhibit less than maximal activity for mitochondrial superoxide dismutase (an antioxidant enzyme). In the present study, the powdered milk samples were found to contain 0.60-0.99mg of manganese per 100g (Table 1). These values are by far higher than that reported for fresh cow milk which is 0.004mg/100g (Kataoka *et al.,* 1991). From Table 2, a 10g portion of the powdered milk samples has been shown to contain 0.06-0.099mg of manganese. Therefore the contribution of the powdered milk samples to the estimated safe and adequate dietary intake of manganese in children is 3.0-9.9% and 1.0-5.0% in adults.

Conclusion: This study has brought to focus the mineral element composition of powdered milk. The product was found to be wholesome with regards to the content of major and trace elements. With reference to the recommended intake of mineral nutrients, extensive benefits could be derived from this source if the milk is consumed regularly.

Acknowledgement

The author thanks Mr. N. A. Udofia (Chief Technologist), Central Research Laboratory, University of Uyo, Uyo, Nigeria for technical assistance.

References

Akpanyung, E.O., A.P. Udoh and M.U. Eteng, 2001. Antinutrient profile and chemical composition of custard powder produced in Nigeria. J. Food Sci. Tec., 38: 120-123.

AOAC, 1984. Official Methods of Analysis. 14th ed. Association of Official Analytical Chemists. Washington DC.

Baly, D.L., C.L. Keen and L.S. Hurley, 1985. Pyruvate carboxylase and PEP carboxykinase activity in developing rats: effect of Mn deficiency. J. Nutr., 115: 872-879.

Beard, J.L., 2001. Iron biology in immune function, muscle metabolism and neuronal function. J. Nutr., 131: S568-S579.

Berne, R.M. and M.N. Levy, 1998. Physiology. 4th ed. Mosby Inc. St. Louis. US.

Bhaskaram, P., 2001. Immunobiology of mild nutrient deficiencies. Br. J. Nutr., 85: S75-S80.

Black, R. E., 2003. Zinc deficiency, infectious disease and mortality in the developing world. J. Nutr., 133: S1485-S1489.

Blum, M., 1996. Iron fortification of foods. Nutriview, 3: 1-3.

Blum, M., 1997. Food fortification: a key to end micronutrient malnutrition. Nutriview (special edition). A Publication of Roche Vitamins, Europe, Basel, Switzerland.

Bowley, A., 2005. Conference report. Nutriview, 1: 5 – 6.

Brown, K. H. and S. E. Wuehler, 2002. Zinc and human health: results of recent trial and implications for programme interventions and research. Micronutrient Initiative. Ottawa. Canada International Research Centre.

Burch, R.D. and H.K.J. Hahn, 1983. Copper. In: Zumkley, H. (Ed.), Spurenelement. Stuttgart: Georg Thieme Verlag.

Davis, W.H., 1970. Does potassium deficiency hold a clue to metabolic disorders associated with liability to coronary heart disease? S. Afr. Med. J., 44: 1297-3000.

Davis, B.B. and F.G. Knox, 1970. Current concepts of the regulation of urinary sodium excretion – a review. Am. J. Med., 259: 373-382.

Davis, C.D. and J.L. Greger, 1992. Longitudinal changes of Mn dependent SOD and other indices of Mn and Fe status in women. Am. J. Clin. Nutr., 55: 747-752.

FNB, 1989. Recommended Dietary Allowances. 10th ed. Food and Nutrition Board. National Research Council. National Academy of Science. US.

Gerrior, S., J. Putnam and L. Bente, 1998. Milk and milk products: their importance in the American diet. Food Rev., 21: 29-43.

Hurley, L.S. and C.L. Keen, 1989. Manganese. In: Mertz, V. (Ed.), Trace Elements in Human and Animal Nutrition. 5th ed. Acad. Press. San Diego, CA.

International Zinc Nutrition Consultative Group (IZiNCG) Technical Doc HI, 2004. Assessment of the risk of zinc deficiency in populations and options for its control. Food and Nutr. Bull., 25: S130-S162.

Jensen, R.G., 1998. Handbook of Milk Composition. Academic Press, New York.

Kataoka, K., T. Nakae and T. Imamura, 1991. Comparative studies on the milk constituents of various mammals in Japan. Japan J. Dairy Sci., 20: 222-232.

Kruse-Jarres, J.D., 1994. Rare essential trace elements. Annals Nestlé, 52: 138-141.

Latham, M.C., 1997. Human Nutrition in the Developing World. FAO Foods and Nutrition Ser. No 29. Rome.

MacPhail, A.P. and T.H. Bothwell, 1992. The prevalence and causes of nutritional iron deficiency anaemia. In: Fomon, SJ., Zlotkin, S. (Eds.), Nestle Nutrition Workshop Series #30, Raven Press. New York.

Malecki, E.A. and J.L. Greger, 1985. Mn protects against heart mitochondrial lipid peroxidation in rats fed high concentrations of dietary polyunsaturated fatty acids. J. Nutr., 125: 27-33.

Maziya-Dixon, B.M., I.O. Akinyele, E.B. Oguntona, S. Nokoe, R.A. Sanusi and E.M. Harris, 2004. Nigeria Food Consumption and Nutrition Survey 2001-2003. Summary. IITA. Ibadan. Nigeria.

Miller, G.D., J.K. Jarvis and L.D. McBean, 1999. Handbook of Dairy Foods and Nutrition. 2nd ed. Boca Raton. FL. CRC Press.

Muller, H.G., 1970. Traditional cereal processing in Nigeria and Ghana. J. Agri. Sci., 3: 187-191.

Murray, R.K., D.K. Granner, P.A. Mayes and V.W. Rodwell, 2000. Harper's Biochemistry. 25th ed. McGraw Hill. New York.

Passmore, R. and M.A. Eastwood, 1986. Human Nutrition and Dietetics. 8th ed. Churchill Livingstone. UK.

Peeley, R.M., 1998. Major mineral elements in dairy products. J. Am. Diet. Assoc., 61: 505-510.

Sarkar, B., 1994. Copper. In: Sailer, H. G., Sigel, A., Sigel, H. (Eds.), Metals in Clincial and Analytical Chemistry. Marcel Dekker Inc. New York.

Stryer, L., 2000. Biochemistry. 4th ed. W. H. Freeman and Co. New York.

Suelter, C.H., 1970. Enzymes activated by monovalent cations. Science, 168: 789-795.

Topian, L., 1979. The relationship of salt to hypertension. Am. J. Clin. Nutr., 32: 2739-2741.

Trowbridge, F. and R. Martorell, 2002. Forging effective strategies to combat iron deficiency. Summary and Recommendations. J. Nutr., 85: S75-S80.

Vogel, A.I., 1969. A Textbook of Quantitative Inorganic Analysis. 3rd ed. Longman Group Ltd. London.

WHO, 1996. Trace Elements in Human Nutrition and Health. WHO. Geneva. Switzerland.

Woo, R.U., K.R. Daniels and E.S. Houston, 1995. Regulation of energy balance. Ann. Rev. Nutr., 5: 411-418.

Yellen, G., 2002. The voltage gated potassium channels and their relatives. Nature, 419: 35-42.

Zololor, A.J., 1997. Intracellular and extracellular biology. Can. J. Biol., 51: 77-79.