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ASSESSING THE LEVEL OF MACRO MINERALS IN RAW MILK AND CERTAIN DAIRY PRODUCTS

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ABSTRACT

Milk and dairy products are vital sources of essential macro minerals, including calcium, phosphorus, magnesium, potassium, and sodium. This study aimed to evaluate the concentrations of these macro minerals (Ca, P, Mg, K, and Na) in raw milk, Ultra-high temperature (UHT) milk, dried milk, Kareish cheese, white soft cheese, and yogurt. Additionally, it sought to compare these levels to the Recommended Dietary Allowances (RDA) established by the U.S. National Research Council in 1989 for adults.

A total of 180 random samples of various dairy products were collected from Assiut Governorate, Egypt, from May 2023 to June 2024. The concentrations of macro minerals were determined using an atomic absorption/flame spectrophotometer. The results revealed the following calcium levels: 1.286%, 0.853%, 1.374%, 2.658%, 1.339%, and 1.114% in raw milk, UHT milk, dried milk, Kareish cheese, white soft cheese, and yogurt, respectively. For phosphorus, the concentrations were 1.084%, 0.632%, 0.903%, 2.188%, 2.220%, and 0.891%, respectively. These findings indicate that milk and dairy products serve as excellent sources of calcium and phosphorus. However, they are moderate sources of magnesium (0.219%–0.289%) and potassium (0.956%–1.728%). Sodium levels, on the other hand, were generally low in the examined products, except for Kareish cheese and white soft cheese, which recorded higher concentrations of 2.971% and 1.295%, respectively. The study also explored the health implications of these macro mineral concentrations, underlining their nutritional importance for consumers.

***Key words*:** Macro elements, raw milk, dairy products, Assiut, Egypt

INTRODUCTION

Milk and dairy products are considered very important natural complete foods in the daily human diet at all stages of life, which constitute a high percentage of the diet, 50-64% in children intake, but in adolescents and adults 40% and 32–41%, respectively (NDNS, 2020), due to highly nutritive values that contain minerals, vitamins, sugars, fats, and proteins (Givens, 2020). Minerals in milk include two large categories; microelements and macro-elements.

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Macro elements of milk are defined as the elements that are present in milk in large percentages in relation to other elements (Qin *et al.,* 2021). Milk macroelements include Ca, P, Mg, K, and Na, which occur in many forms as salts and inorganic ions or are linked to other components, such as fats, carbohydrates, proteins, and nucleic acids (Newton *et al.,* 2021) in a form that can be easily and quickly digested. The importance of macro minerals in milk comes from the thermostability of milk and its ability to transfer Ca and P in high quantities to human in a simple form (Franceschi *et al.,* 2023) and their effects on human health as in diet-conscious consumers, women and children (Koljonen *et al.,* 2021) which considered essential for the life due to its role in bone structure, muscular contraction, hemostasis and act as a source of energy (Dineva *et al.,* 2022) as Calcium which play important roles in the regulation of many structural and vital functions in skeletal health (bones, teeth) (preventing osteoporosis) (Serna & Bergwitz, 2020), muscle contraction, neurotransmitter secretion (Li *et al.,* 2022) and assists in cardiovascular maintenance which prevent hypertensive disorders (Shertukde *et al.,* 2022). In women, calcium plays a very important role in the vascular function of mothers and their fetuses (Cormick & Beliz´an, 2019). On the other hand, along with calcium, phosphorus is considered one of the most important minerals in the body, which work together to build bones and teeth (Kalwar *et al.,* 2023; McAlister *et al.,* 2020). The phosphorus percentage in the bones and teeth reaches 85% of total body phosphorus, which is also essential for energy storage of the body and the equilibrium of kidney function (Serna and Bergwitz 2020). Milk is considered a good source of calcium and phosphorus, which contain (150-200 mg) and (100–150 mg) per 100 mL of milk, respectively. In addition, magnesium plays an important role in bone formation, as it helps calcium absorption in the bone and activates vitamin D in the kidneys, which is also necessary for bone health (Qin *et al.,* 2023). The optimal amount of magnesium (at the normal limit) is also associated with increased bone density, improved bone crystal formation, and decreased risk of injury & osteoporosis in postmenopausal women. Milk and dairy products are considered excellent sources of potassium (Ateteallah and Hassan 2017), which is present mainly in intracellular fluid in concentrations of 2 g/kg, which regulates the osmotic pressure of the cell and activates respiratory enzymes (Kumssa *et al.,* 2021). On the other hand, sodium concentrations in the body are 1.4 g/kg, which are present extracellularly and maintain the osmotic pressure of the extracellular fluid and activate amylase enzymes. Excessive intake of sodium leads to hypertension. Milk is not a rich source of sodium. National Research Council (1989) established that the Recommended Dietary Allowances (RDA) were 200-1300, 100-1250, 300-420, and 400-2600 mg in Ca, P, Mg, and K, depending on a human's age and sex, while the Dietary Guidelines for Americans recommend adults limit sodium intake to less than 2,300 mg. Although milk contains a very small amount of minerals (about 8–9 g/L). It is considered very important and is a good source of calcium, phosphorus, magnesium, potassium, and sodium. This study aims to assess the level of macro minerals (Ca, P, Mg, K, and Na in raw milk, UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt) and the percentage of the mean of macro element concentrations in the examined samples to (RDA) for adults in Assiut City, Egypt.

MATERIALS AND METHODS

Collection of samples:

In Assiut City, Egypt, a total of 180 randomly collected samples of raw milk, UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt were collected. The samples were gathered in sterile, dry, and clean containers between May 2023 and June 2024, and were sent to the laboratory without any delay.

Preparation and digestion of samples:

Milk digestion (Slavin *et al.*, 1975):

Using a sterile glass pipette, 25 ml of each milk sample was taken and put in a clean and dried Erlenmeyer flask. The Erlenmeyer flasks with milk samples were placed in a 100°C hot air oven for one hour and then moved to 50°C for 24 hours until the milk sample's water evaporated. Added to each flask 25 ml (equal volumes of concentrated nitric acid and 72% perchloric acid) as a digestion mixture, then to facilitate the processes of digestion, shake and allow the acid to react at room temperature for 24 hours. Place the flasks on a hot plate at approximately 100 °C and shake them before adding several milliliters of concentrated nitric acid while they are heating until each sample becomes colorless, which indicates complete digestion of the sample. Then evaporate until the brown gas, nitric oxide NO_3, disappears from the flask. After cooling the samples, filter them with filter paper. The final volume of the digested sample was 25 ml after washing several times with ion-free water. The samples were stored in a refrigerator for examination.

Yogurt and Cheese Digestion (Thomas *et al.*, 1980):

Samples of 8 g of yogurt or cheese were added to 150 ml, and warmed to 50°C, then 10 ml of 12% ($ZnSO_4$) and 10ml of 0.5 N (NaOH) were added and left at 50°C for 10 minutes, cooled, diluted to 200 ml, and finally, filtration was determined.

Assessment of the level of macro minerals (Ca, P, Mg, K, and Na):

A model atomic absorption/flame spectrophotometer named Shimadzu Atomic Absorption/Flame Spectrophotometer Model AA630-02P/N204-27600-02AA630-02 was used in Kyoto, Japan. Assessing the level of macro minerals (Ca, P, Mg, K, and Na) in raw milk, UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt). The analysis of line wavelength, lamp current, slit width, burner flame and support gas flow (e/min) for it was conducted. Line wavelength: nm, lamp current: mA, slit width, burner flame: cm air-C_2H_2, support gas flow (e/min.).

RESULTS

Table 1: Calcium concentrations (ppm) in the examined raw milk and dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt) No./30.

Samples	Minimum (ppm)	Maximum (ppm)	Mean (ppm) ± SE	Std. Dev.
Raw milk	1085.54	1417.76	1286.64 ± 15.89^{c}	87.05
UHT milk	753.76	974.32	853.78 ± 11.41^{e}	62.50
Dried milk	1105.34	1454.86	1374.37 ± 14.87^{b}	81.47
Kareish cheese	2165.65	2935.84	2658.67± 46.45^{a}	254.45
White soft cheese	1194.84	1416.51	1339.15± 13.66^{bc}	74.84
Yogurt	953.34	1287.84	1144.72± 19.52^{d}	106.89

Table 2: Phosphorus concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt) No. /30

Samples	Minimum (ppm)	Maximum (ppm)	Mean (ppm) ± SE	Std. Dev.
Raw milk	963.74	1174.87	1084.25±8.37^{b}	45.89
UHT milk	584.86	778.32	632.31±7.67^{d}	41.34
Dried milk	864.87	983.76	903.37±6.00^{c}	32.87
Kareish cheese	1985.54	2476.87	2188.97±47.20^{a}	258.53
White soft cheese	984.54	2476.87	2220.32 ±65.04^{a}	356.24
Yogurt	745.87	945.87	891.89±9.66^{c}	52.89

Table 3: Magnesium concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt) No. / 30

samples	Minimum (ppm)	Maximum (ppm)	Mean (ppm) ± SE	Std. Dev.
Raw milk	183.63	312.76	227.23±7.48^{cd}	41.00
UHT milk	102.65	294.56	258.84±6.98^{b}	38.24
Dried milk	217.82	254.1	233.73±1.95^{cd}	10.71
Kareish cheese	215.45	327.24	289.48 ±5.93^{a}	32.48
White soft cheese	205.47	265.34	239.56±4.09^{c}	22.41
Yogurt	176.11	285.45	219.95±5.66^{d}	31.00

Table 4: Potassium concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt) No. / 30

samples	Minimum (ppm)	Maximum (ppm)	Mean (ppm) ± SE	Std. Dev.
Raw milk	1023.64	1265.67	1182.30±13.70^{d}	75.07
UHT milk	1158. 48	1484.63	1272.29±15.48^{c}	84.82
Dried milk	1221.34	1474.86	1366.67±14.08^{b}	77.14
Kareish cheese	1437.94	1863.83	1728.83±26.99^{a}	147.83
White soft cheese	1204.53	1397.87	1298.53±8.38^{c}	45.91
Yogurt	854.34	1085.93	956.68±13.28^{e}	72.74

Table 5: Sodium concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt) No. / 30

samples	Minimum (ppm)	Maximum (ppm)	Mean (ppm) ± SE	Std. Dev.
Raw milk	295.84	552.86	386.23 ±12.51^{cd}	68.53
UHT milk	349.12	479.96	398.31 ±7.25^{cd}	39.73
Dried milk	396.86	465.17	423.58±4.15^{c}	22.71
Kareish cheese	2185.27	3186.85	2971.35±48.65^{a}	266.49
White soft cheese	1204.53	1317.47	1295.18±6.54^{b}	35.82
Yogurt	285.76	496.53	349.14±8.70^{d}	47.65

DISCUSSIONS

The impact of macro minerals in milk on human health, particularly in diet-conscious consumers, women, and children, is significant. Raw milk and dairy products contain the most significant macro minerals, which are Ca, P, Mg, Na, and K. Calcium is the most abundant element present in large percentages in milk, which plays a very important role in its ions controlling the processes of absorption and reabsorption of calcium from the elementary tract, kidney, and skin, leading to the degree of bone rigidity. Depending upon human age and sex A recommended daily allowance of calcium is ranged from 200-1300 mg, and the deficiency from that causes many bone diseases, such as osteoporosis. Table (1) showed that the incidence of calcium concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt. Nearly similar results were obtained by Stocco *et al.* (2019); Fantuz *et al.* (2022) and Newton *et al.* (2023) for raw milk, but high

concentrations (approximately 1900 to 2015 mg/L) were reported by Ahmad *et al.* (2008) and Singh (2023) and lower values (approximately 750 to 1120 mg/L) were obtained by Patino *et al.* (2007) and Chen *et al.* (2020). In dairy products, nearly similar results were obtained by Ateteallah and Hassan (2017) for kareish cheese, Qaisar and Mustafa (2020) for white soft cheese and yogurt, Petrović *et al.* (2016) for UHT milk and dried milk.

Table 6: The percentage of the mean of macro element concentrations in the examined raw milk and dairy products to the Recommended Dietary Allowances (RDA) established by the U.S. National Research Council (1989) for adults.

	Element	Ca	p	Mg	K	Na
RDA	ppm	1000	700	420	2000	2000
Raw milk	Mean (ppm) ± SE	1286.64 ± 15.89	1084.25 ±8.37	227.23 ±7.48	1182.30 ±13.70	386.23 ±12.51
	% RDA	1.287	1.549	0.541	0.591	0.193
UHT milk	Mean (ppm) ± SE	853.78 ± 11.41	632.31 ±7.67	258.84 ±6.98	1272.29 ±15.48	398.31 ±7.25
	% RDA	0.854	0.903	0.616	0.636	0.199
Dried milk	Mean (ppm) ± SE	1374.37 ± 14.87	903.37 ±6.00	233.73 ±1.95	1366.67 ±14.08	423.58 ±4.15
	% RDA	1.374	1.291	0.557	0.683	0.212
Kareish cheese	Mean (ppm) ± SE	2658.67 ± 46.45	2188.97 ±47.20	289.48 ±5.93	1728.83 ±26.99	2971.35 ±48.65
	% RDA	2.659	3.127	0.689	0.864	1.486
White soft cheese	Mean (ppm) ± SE	1339.15 ± 13.66	2220.32 ±65.04	239.56 ±4.09	1298.53 ±8.38	1295.18 ±6.54
	% RDA	1.339	3.172	0.570	0.649	0.648
Yogurt	Mean (ppm) ± SE	1144.72 ± 19.52	891.89 ±9.66	219.95 ±5.66	956.68 ±13.28	349.14 ±8.70
	% RDA	1.145	1.274	0.524	0.478	0.175

The data summarized in Table (2) showed that the incidence of phosphorus concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt. These results agreed with those obtained by Fantuz *et al.* (2022) for raw milk but had a higher concentration obtained by Stocco *et al.* (2019) for raw milk. On other hand, nearly similar results were obtained by Qaisar and Mustafa (2020) for white soft cheese and yogurt. Phosphorus is considered an essential element for bone and teeth health, with 85% of the body's phosphorus found in them, and it works together with calcium to build bone structures of the body. On the other hand, phosphorus acts to produce energy, cell signaling, and helps in the kidneys function. A recommended daily allowance of phosphorus is 100-1250 mg, depending on human age and sex. In addition to that, magnesium plays an important role in bone formation, as it helps calcium absorption in the bone and activates vitamin D in the kidneys, which is also necessary for bone health. The optimal amount of magnesium (at the normal limit) is also associated with increased bone density, improved bone crystal formation, and decreased risk of injury osteoporosis in postmenopausal women. A recommended daily allowance of magnesium is 300-420 mg, depending on human age and sex.

Results in Table (3) showed that the incidence of magnesium concentrations

(ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt. These results agree with those obtained by Ahmad *et al.* (2008); Islam *et al.* (2014); Stocco *et al.* (2019); and Fantuz *et al.* (2022). The data obtained are lower than the (approx. 60 to 80 mg/L) that were reported by Patino *et al.* (2007) and Chen *et al.* (2020). Otherwise, the obtained data were higher than concentrations (235 mg/L) for raw milk, but nearly similar results were obtained by Qaisar and Mustafa (2020) for white soft cheese and yogurt. Also, similar results were obtained by Petrović *et al.* (2016) for UHT milk and dried milk. Milk and dairy products are considered excellent sources of potassium, which is present mainly in intracellular fluid in concentrations of 2 g/kg, which regulates the osmotic pressure of the cell and activates respiratory enzymes. The recommended daily allowance of potassium is 400-2600 mg, depending on human age and sex.

Data obtained and plotted in Table (4) showed the incidence of potassium concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt. These results agreed with those obtained by Fantuz *et al.* (2022). But, lower than values (approx. 640 to 860 mg/L) that were observed by Chen *et al.* (2020) in raw milk. Also, the obtained data are nearly similar to results obtained by Ateteallah and Hassan (2017) for kareish cheese, Qaisaret and Mustafa (2020) for white soft cheese and yogurt, while, similar to Petrović *et al. (*2016) for UHT milk and dried milk. Sodium concentrations in the body are 1.4 g/kg, which present extracellularly and maintain the osmotic pressure of the extracellular fluid and activate amylase enzymes, and the excessive intake of sodium is of importance because it can lead to hypertension. Milk is not a rich source of sodium.

Results obtained in Table (5) showed that the incidence of sodium concentrations (ppm) in the examined raw milk and some dairy products (UHT milk, dried milk, kareish cheese, white soft cheese, and yogurt. These results agreed with those obtained by Ateteallah and Hassan (2017) and Fantuz *et al.* (2022). The results of Na concentrations were similar to the results obtained by Islam *et al.* (2014) and Chen *et al.* (2020).

Obtained data in Table (6) summarized that the percentages of the mean of macro element concentrations in the examined raw milk and dairy products (UHT milk, dried milk, kareish cheese, white soft cheese and yogurt) to the Recommended Dietary Allowances (RDA) established by the U.S. National Research Council (1989) for adults which were: 1.286 %, 0.853%, 1.373 %, 2.658 %, 1.267 % and 1.073 % for Ca. while, data were: 1.497%, 0.891 %, 1.291 %, 3.124 % 1.525%, and 1.279 % for P, respectively. That indicated that the examined milk and dairy products are an excellent source of Ca and P. On the other hand, the milk and dairy products examined are moderate sources of Mg, and K. All examined milk and dairy products are poor source of Na except kareish, white soft cheese.

CONCLUSION

From the results of assessing the level of macro minerals in raw milk and dairy product samples, it appears that the presence of most macro-elements was within the permitted limits. In addition, from the detected amounts of Ca and P, the examined milk and dairy products are an excellent source of Ca and P, while all examined milk and dairy products are considered moderate sources of Mg and K. In addition to that, all examined milk and dairy products are poor sources of Na except kareish and white soft cheese.

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تم جمع ١٨٠ عينة عشوائية من اللبن الخام وبعض منتجات الألبان (اللبن المعقم، اللبن المجفف، الجبن القريش، الجبن الأبيض الطري والزبادي) في مدينة أسيوط بمصر خلال الفترة من يناير ٢٠٢٣ إلى مارس ٢٠٢٤ لقياس تركيز أملاح الكالسيوم والفوسفور والماغنسيوم والبوتاسيوم والصوديوم في اللبن الخام وبعض منتجات الألبان ونسبة العناصر الكلية ومقارنتها بالتراكيز الموصي بها طبقا لمجلس البحوث القومي الأمريكي (١٩٨٩) (RDA) في اللبن الخام ومنتجات الألبان للبالغين وأظهرت النتائج أن نسبة تراكيز العناصر الكلية في اللبن الخام ومنتجات الألبان التي تم فحصها للبالغين وكانت ١,٢٨٦٪، ٠,٨٥٣٪، ١,٣٧٣٪، ٢,٦٥٨٪، 1.339% و1.114% للكالسيوم، وكانت 1.084%،0.632%، 0.903%، 2.188%، 2.220% و 0.891% للفوسفور على التوالي وهذا يدل على أن اللبن ومنتجات الألبان المفحوصة هي مصدر ممتاز لكلا منهما ومن ناحية أخرى فإن اللبن ومنتجات الألبان المفحوصة هي مصدر معتدل للمغنيسيوم والبوتاسيوم حيث بلغت نسبة الماغنسيوم 0.227% و0.258 % و0.233 % و 0.289 % و 0.239 % و 0.219 %. وكانت 1.182 % و 1.272 % و 1.366% و 1.728 % و 1.298 % و 0.956 % للبوتاسيوم علي التوالي. وكانت كل عينات اللبن ومنتجات الألبان التي تم فحصها هي مصدر فقير للصوديوم باستثناء الجبن القريش والأبيض الطري الذي 2.971 % و 1.295% للجبن القريش و الأبيض الطري على التوالي. وتم مناقشة الأهمية الصحية لتلك الاملاح بالنسبة للمستهلكين.