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Evaluation of Silicon Concentration in Milk from Different Species and in Certain Dairy Products in Egypt

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ABSTRACT

Silicon plays an important role in bone formation and connective tissue metabolism. Although biological interest in this element has recently been increased, limited information exists about the silicon concentration of foods. Further knowledge relating the relationship between dietary silicon and human health, reliable silicon concentration in food is required. Therefore, the object of this study focused on the silicon concentration in some Egyptian milk and some dairy products. Milk from different species and some dairy products commonly consumed in Egypt were analyzed for silicon concentration. The samples were analyzed using Agilent microwave plasma atomic emission spectrometry following microwave- assisted digestion with nitric acid. The results revealed the linearity of this method and the recovery ranged from 98 – 100 % for milk and 96 – 98 for cheese. The data showed the highest concentration of silicon was found in camel milk (mean = 3.34 ± 0. 12 ppm), lowest concentration in buffalo milk (mean = 0.20 ± 0.01 ppm). Also, it was found the mean values of silicon in goat and cow milk were = 2.28 ± 0.09 ppm and 0.94 ± 0.03 ppm, respectively. The mean values of fresh skim milk and skim milk powder were 0.80 ± 0.04 and 33.11 ± 2.3, respectively. The silicon concentration in processed cheese was higher than that in soft cheese. However, yogurt was of the highest silicon concentration, compared to fresh milk and cheeses. The present study provided the importance of the primary data obtained dealing with the silicon concentration of some Egyptian milks and dairy products.

Keywords: silicon, skim, buffalo, cow, camel, goat milk, soft cheese, processed cheese, yoghurt, microwave plasma atomic emission spectrometry

INTRODUCTION

Silicon (Si) is the third most abundant trace element of the human body and is of a potential beneficial influence, especially, in regard to connective tissues bone, skin, hair, nails and blood vessels. It also of vital effect on the protection from atherosclerotic vascular alterations and lowers plasma lipids (Sripanyakorn *et al.*2005) Limited knowledge is available on its required dietary intakes, and optimal levels needed for the prevention of bone and cardiovascular diseases. Different studies on the beneficial effect of silicon on bone health were reported. It usually exist in an abundant levels in foods derived from plants, and cereals, as silicon dioxide (SiO_2, silica) and orthosilicic acid [Si $(OH)_4$]. Lower levels, however, are detected in foods from animal sources Orthosilicic acid is the major silicon species presents in drinking and mineral water.. Insoluble phytolithic silicon silica are present in plants and plant-based foods but intestinal uptake proceeds following luminal hydrolysis to orthosilicic acid The silicon concentration in milk and dairy products appears to be low (Reffitt *et al.*, 1999, EVM, 2003, Powell *et al.*, 2005 and Jugdaohsingh, 2007)

Little information on the silicon concentration of foods has been reported, primarily due to difficulties associated with the analytical procedures required for silicon analysis and there are limited data available for milk and dairy products especially for Egyptian milks and its products.

Therefore, the aim of this study was to determine silicon level in milk from different animal species and some dairy products,

MATERIALS AND METHODS

Whole raw buffalo milk was obtained from Mahalat Mousa Station belonging to Animal Production Res. Institute, whole raw cow milk from Gemaza Station belongs to Animal Production Research Institute, ARC., Camel milk from Marsa Matroh Station belongs to Animal Production Research Institute, ARC, and the goat milk from Sakha station belongs to Animal Production Research ARC.

UF White soft cheese (3% salt) and yoghurt (prepared from whole buffalo milk) were obtained from the Dairy Processing Unit belong to Animal Production Research Institute. Skim milk powder and processed cheese were randomly collected from the local market in Cairo and stored in refrigerator at 5 ±1 until analysis.

All samples were firstly analyzed for its chemical composition (total solids, fat, protein, lactose and ash) and pH according to AOCA (2007) which are illustrated in Tables (1) and (2).

Table 1. Chemical composition of tested milk samples

Parameters	Milk Samples			
	Buffalo	Cow	Camel	Goat
pH	6.80	6.60	6.5	6.6
T.S (%)	15.83	11.45	11.70	12.20
Fat (%)	6.10	3.00	3.60	3.80
Protein (%)	4.20	3.10	3.00	3.50
Lactose (%)	4.70	4.60	4.40	4.10
Ash (%)	0.82	0.75	0.70	0.80

Table 2. Chemical composition of tested dairy products

Parameters %	Fresh Skim milk	Skim milk powder	White Soft cheese	Processed cheese	Yoghurt
pH	6.72	6.60	6.40	5.40	4.60
T.S	8.83	96.20	37.40	42.00	15.60
Fat	0.11	1.15	18.50	29.00	6.50
Protein	3.20	33.00	14.00	9.50	4.40
Lactose	4.70	54.00	3.50	2.50	3.60
Ash	0.82	8.05	1.40	1.00	1.10

For the determination of silicon using Agilent microwave plasma atomic emission spectrometry.

Microwave digestion was used to prepare the spike samples. Ten mL of HNO_3 was added to accurately weighed ≈ 0.5 g of the sample. A preloaded method for the MARS6 (CEM, Corporation, USA) microwave was used to digest the samples. Once cooled; the solution was diluted quantitatively to 25 mL using ultrapure distilled water.

Silicon standards from 0 – 1.50 mg/l were prepared from a stock standard solution of meta silicate pentahydrate ($Na_2SO_3.5H_2O$, Sigma Chemical Company). Stock solution (1000 mg Si/l) of meta silicate pentahydrate was prepared. The intensity was measured at 251.611nm. Standard reference materials do not exist for silicon in foods samples, so spiking and recovery experiments were used as before for quality assurance.

All measurements were performed using the innovative Agilent microwave plasma atomic emission spectrometry model 4200 MP-AES with nitrogen gas plasma supplied via an Agilent 4107 Nitrogen Generator. The generator alleviates the need and expense of sourcing analytical grade gases. The sample introduction system comprised a double-pass cyclonic spray chamber and the One Neb nebulizer. The innovative 4200 MP-AES features a second-generation waveguide and torch, with mass flow controlled nebulizer gas flow. The 4200 MP-AES has robust toroidal plasma with a central channel temperature of ≈5,000 K that eliminates many of the chemical interferences that are present in FAAS and expands the concentration working range of the 4200 MP-AES when compared with the FAAS. This means that the element specific sample preparation that is commonplace when using FAAS is not necessary when using the 4200 MP-AES, improving ease of use and reducing cost. Some modification has been performed with the first emerging model 4100 MP-AES into model 4200 MP-AES to enhance the performance and to resolve some drawbacks.

An Agilent SPS 3 auto sampler was used to deliver samples to the instrument, allowing the system to be operated unattended. The instrument operated in a fast sequential mode and featured a Peltier-cooled CCD detector. Background and spectral interferences could be simultaneously corrected easily and accurately using Agilent's MP Expert software. The concentrations of silicon were calculated according to the standard curve shown in Fig. (1)

Spiked sample was prepared by adding known concentrations of standard silicon to raw buffalo milk samples and soft cheese. The silicon in these samples was determined by using the same Agilent microwave plasma atomic emission spectrometry conditions. Recovery was calculated by the following equation:

$$\mathbf{R\ \% = (C_s - C_p / C_a).\ 100}$$

Where R (%) is the percent recovery of added standard; C_s is silicon concentration in the spiked sample; C_p is the silicon concentration in the unspiked sample and C_a is the concentration of silicon standard added. Also, the coefficient of variation was calculated as the following equation (Horwitz, 2003):

$$\mathbf{C_v\ (\%) = (SD / mean)\ .100}$$

RESULTS AND DISCUSSION

Silicon concentration in milk and in certain dairy products were determined by microwave plasma atomic emission spectrometry. The standard curve for silicon determination was represented in Fig.(1). The correlation between intensity and concentration showed a linear response with excellent correlation coefficient (r = 1).

The validation of this method was evaluated by determination of recovery of silicon standard in spiked samples of buffalo milk and soft cheese as shown in table (3). It was found that the recoveries of silicon standard in buffalo milk samples were 98 – 100 % for concentrations 1.00 and 2.00 ppm respectively (Table 3). The data also showed the recoveries of the same concentrations of silicon standard in cheese samples were 96 and 98 %, respectively. These demonstrated the satisfactory recovery of the method on the tested dairy samples. The results of linearity and recovery indicated that the microwave plasma atomic emission spectrometry method is reliable for quantifying silicon in dairy samples.

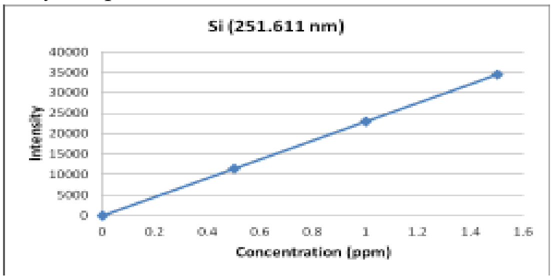

Fig. 1. Standard Curve of Silicon

Table 3. Recovery of silicon standard in buffalo milk and soft cheese

Samples	Si standard ppm	Original Si in milk and soft cheese ppm	Si recovered ppm	Recovery %
Milk	0.50	0. 20	0.69	98
	2.00	0.20	2. 20	100
Soft cheese	0.50	4.4	4.88	96
	2.00	4.40	6.36	98

Silicon concentration in milk from different species

Table (4) showed the silicon concentration in milk from different species (buffalo, cow, camel and goat). It was found that the maximum concentration of silicon was in camel milk samples (mean = 3.34 ± 0.12 ppm) with correlation variation 3.59 %, and the minimum concentration was in buffalo milk samples (mean = 0.2 ± 0.01 ppm) with coefficient of variation 5%. While silicon concentration in cow and goat milk samples were 0.94 ± 0.03 and 2.28 ± 0.09 ppm with coefficient of variation 3.19 and 3.95% respectively.

Table 4. Silicon concentration in milk from different species

Milk types	Silicon concentration (ppm)		
	Range	Mean ± SD	CV %
Buffalo milk	0. 18 - 0. 22	0. 20 ± 0.01	5.00
Cow milk	0.90 - 0.98	0. 94± 0. 03	3.19
Camel milk	3. 24 – 3. 44	3. 34 ± 0. 12	3.59
Goat milk	2.20 – 2. 35	2. 28 ± 0. 09	3.95

Regarding the silicon concentration in certain dairy products (fresh skim milk , skim milk powder, white soft cheese, processed cheese and yoghurt) were represented in Table (5). The mean values of fresh skim milk and skim milk powder were 0.80 ± 0.04 and 33.11 ± 2.30 ppm, respectively. The average of silicon in fresh skim milk agreed with Powell *et al.,* (2005), but the marked skim milk powder was higher than that reported by Bowen, & Peggs, (1984), who found that silicon concentration in skim milk were in range 20 to 27 mg/kg dry wt. Higher level of silicon was detected in processed cheese(5.80 ppm± 0.30), compared with white soft cheese (4.36 ± 0.23). These findings are in harmony with those reported by Powell *et al.,* (2005). Moreover, the results appeared that yoghurt contained higher silicon concentration than fresh milk and cheeses. Data also showed that the coefficient variation of all samples ranged from 3.11 to 6.95 ppm (Table 5).

Table 5. Silicon concentration in skim milk and some dairy products

Items	Silicon concentration (ppm) Range	Mean ± SD	CV %
Fresh skim milk	0. 74 - 0.85	0.80 ± 0.04	5.00
Skim milk powder	30.75 - 35.50	33.11 ± 2.30	6.95
Soft cheese	4.27 - 4.50	4.36 ± 0.23	5.28
Processed cheese	5.53 - 6.12	5.80 ± 0.30	5.17
Yoghurt	13.10 – 13.85	13.50 ± 0.42	3.11

CONCLUSION

The present study demonstrated suitability of the microwave plasma atomic emission spectrometry method for determination of silicon in milk and dairy products. Generally, milk and its products are considered of low silicon concentration. The highest value of silicon found in camel milk, followed by gradual decrease in goat, cow, and buffalo milks, respectively. Processed cheese contained higher level of silicon than soft cheese. The fermented milk as yogurt was the highest in silicon concentration. compared to milk and cheeses. These results give data for the silicon concentration of some Egyptian milks and dairy products, which are important for estimation of dietary intakes of silicon in the Egyptian population and declare the role of dietary silicon in African human health.

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تقييم محتوى السليكون فى الألبان من أنواع مختلفة وبعض المنتجات اللبنية فى مصر

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يلعب السيليكون دورا هاما فى الوظائف الحيوية للإنسان ويزداد الإهتمام به فى الوقت الحالى لأهميتة فى تكوين العظام والأنسجة الضامة. و لكن مازالت المعلومات عن مستوى تركيزة فى الأطعمة محدود وخصوصا فى الأطعمة المصرية التى تتضمن الألبان وبعض منتجاتها. ولدلك هناك ضرورة لتقييم محتوى السيليكون فى الأطعمة التى تتناول يوميا لمعرفة العلاقة بين تناول العنصر اليومى وصحة الإنسان . ولدلك تهدف هدة الدراسة لتقدير محتوى السيليكون فى الألبان من حيوانات مختلفة وبعض المنتجات اللبنية الأكثر استهلاكا فى مص وقد تم تقدير السيليكون فى عينات لبن جاموسى ، بقرى ، ماعز ، نوق وبعض المنتجات اللبنية مثل اللبن الفرز الطازج ، اللبن الفرز الجاف،الجبن الأبيض الطرى ، الجبن المطبوخ ،اليوجهورت. وقد تم تقدير السيليكون فى هذة العينات و أظهرت النتائج الأتى : دقة وحساسية الطريقة المستخدمة وملائمتها لتقدير السيليكون فى اللبن ومنتجاتة وان كفاءتها تصل إلى 98% - 100% و 96 -- 98 % بالنسبة للبن والجبن على التوالى. كما أوضحت النتائج أن لبن النوق يحتوى على النسبة الأعلى من السيليكون (3.34 ± 0.12 جزء فى المليون) يلية لبن الماعز (2.28± 0.09)ثم البقرى(0.94±0.03) ثم الجاموسى(0.20±0.01) . وكان متوسط مستوى السيليكون فى اللبن الفرز واللبن الفرز الجاف يتراوح بين 0.80 ± 0.04 و 33.11 ± 2.30 جزء فى المليون على التوالى. بينما وجد ان متوسط مستوى السيليكون فى الجبن المطبوخ 5.8 ± 0.3 جزء فى المليون وهو أعلى من الجبن الأبيض الطرى 4.36 ± 0.23جزء فى المليون. و وجد متوسط مستوى السيليكون فى اليوجهورت كمنتج متخمر 13.50± 0.42 جزء فى المليون وهو أعلى من اللبن الطازج والجبن . وبالتالى فإن هده الدراسة تعطى معلومات أولية عن محتوى السيليكون فى بعض الألبان و المنتجات اللبنية المصرية التى يمكن أن تساعد فى تحديد تركيزات السيليكون فى الاطعمة التى يتناولها الانسان المصرى