Nutritional evaluation of processed beverages sold in Korea focusing on calcium, potassium, magnesium and boron contents

MI-KYEONG CHOI – YUN-JUNG BAE – MI-HYUN KIM

Summary

This study aimed at evaluation of the nutritional value of processed beverages commonly sold in Korea, focusing on calcium, potassium, magnesium and boron. The beverages collected (91 products sold in Korean retail stores) were classified into 12 types (fruit juices, fruit beverages, carbonated beverages, sports drinks, caffeinated beverages, alcoholic beverages, teas, natural mineral water, milks, fermented milks, soymilks and other mixed beverages) and concentration of calcium, potassium, magnesium and boron was analysed in them using inductively coupled plasma optical emission spectroscopy. Calcium concentration was highest at 993.8 mg·l^{-1} in fermented milks, followed by milks (599.9 mg·l^{-1}). Potassium was highest at 1 693.7 mg·l^{-1} in fermented milks, followed by soymilks (1 613.7 mg·l^{-1}). Magnesium was highest in soymilks (138.3 mg·l^{-1}), followed by fermented milks (91.2 mg·l^{-1}). Boron was highest at 1.7 mg·l^{-1} in soymilks, followed by fruit juices (1.3 mg·l^{-1}). When the mineral concentration of the beverages was evaluated per one dollar and energy, similar results were obtained. Among the various beverage groups, dairy milks, soymilks and fruit juices had greater value in mineral nutrition in terms of concentration, cost effectiveness and nutritional density.

Keywords

beverage; calcium; potassium; magnesium; boron

Beverage consumption in Korea has dramatically increased due to increased accessibility of beverages, changing food trends as well as due to food industry expansion and development from the end of the 20th century to the beginning of the 21st century [1, 2]. Drinking beverages primarily contributes to water intake. Consumption of high energy-dense beverages such as sugar-sweetened beverages (SSB), milks, alcohol and others also affect total energy intake [3–5]. As the intake of high energy-dense beverages, in particular SSB, has increased, so has the occurrence of health problems associated with the excessive intake of SSB. Therefore, many studies reported the various adverse consequences associated with SSB intake, such as dental caries [6], obesity [7, 8] or type 2 diabetes [9]. These findings were the basis for establishing a policy of desirable beverage consumption, such as promoting plain water intake [10] and adding taxes to SSB in USA [11]. As a consequence, according to a recent study using National Health and Nutrition Examination Surveys, overall beverage and SSB consumption in USA declined for children and adults from 2003 to 2014 [12]. Although absolute intake of beverages among Koreans is lower than in USA, the consumption of beverages including milk products in Korea has been steadily increasing [2]. In particular, the beverage intake of adolescents aged 12–18 years was shown to be about twice as high as that of children aged 6–11 years in Korea. The beverage intake of Korean adults in their 20s was 1.5 times higher than of adolescents, and diminished with increasing age after 30 [2]. Based on an earlier report, the highest consumption frequency of carbonated beverages both non-diet (regular) and diet (sugar-free or artificially sweetened) beverages was found for adolescents aged 12–18 years compared to other age groups in Korea [13].

Beverages can play an important role in mineral supply in addition to hydration and energy supply. Milks are already known as the best source of calcium, while (bottled) natural mineral wa-

Mi-Kyeong Choi, Mi-Hyun Kim, Division of Food Science, Kongju National University, Daehak-ro 54, Yesan 32439, South Korea.
Yun-Jung Bae, Division of Food Science and Biotechnology, Korea National University of Transportation, Daehak-ro 61, Jeungpyeong 27909, South Korea.

Correspondence author:
Mi-Hyun Kim, e-mail: mhkim1129@kongju.ac.kr

ter contains various minerals such as calcium, potassium and magnesium [14]. Minerals play a crucial role in regulating various physiological functions in the human body despite their low requirement [15]. It was also reported that the intake of some minerals, such as calcium, potassium or magnesium, has a negative correlation with blood pressure and blood lipid levels, suggesting possible cardiovascular disease-preventing effects [16, 17]. However, despite the importance of minerals for health, research on focused on the mineral value of beverages is relatively scarce. Insufficient calcium intake has been one of the significant nutritional issues in Korea. The average calcium intake of Koreans falls below the Recommended Intake (*RI*) levels, with only 68.0 % of calcium *RI* consumed. In the case of Korean adolescents aged 12–18 years, calcium intake is only 63.7 % of the *RI* levels [2]. Potassium is also one of the minerals that are assessed as insufficiently intaken by Koreans. Minerals such as magnesium or boron are also known as important minerals for the health of adolescents e.g. regarding skeletal growth, but research on their intake and the content in foods is insufficient. Considering the high consumption of beverages by adolescents, it is necessary to assess the beverages' nutritional value, focusing on minerals that play an important role in growth and nutrition.

The amount of minerals contained in the beverages can vary depending on the type of ingredients, water sources, additives and other factors. However, data on concentration are available only for some minerals. In Korea, most beverages are required to be labelled regarding nutritional data, but the only mineral included in the mandatory labelling scheme is sodium, except for mineral-fortified products. Therefore, this study aimed to evaluate the mineral nutritional value of processed beverages sold in Korea by analysing concentration of calcium, potassium, magnesium and boron in them. Additional to comparison of mineral concentration, also cost-effectiveness against the purchase price and nutritional density for energy were evaluated. Further, the contribution rate relative to the dietary reference intakes (*DRI*s) of adolescents [18] was evaluated by reflecting the high consumption of beverages by Korean adolescents.

MATERIALS AND METHODS

Classification of beverages and purchase

Based on the classification of the Ministry of Food and Drug Safety in Korea, beverages were grouped into 12 categories: fruit juices, fruit beverages, carbonated beverages, sports drinks, caffeinated beverages, alcoholic beverages, mixed beverages, teas, natural mineral water, milks, fermented milks and soymilks [19]. Fruit juices contained 95 % or more of fruit and vegetable juice, while fruit beverages contained 10 % or more of fruit and vegetable juice. Carbonated beverages included sweetened or unsweetened ones, both diet (sugar-free or artificially sweetened) and non-diet (regular) forms. Caffeinated beverages included coffees and energy drinks. Mixed beverages formed a separate group.

As a first step when collecting samples of processed beverages, raw data from the 2010–2012 Korean National Health and Nutrition Examination Survey were analysed and 141 high intake beverages were listed [20]. At this time, by checking the product names of each type of beverage in the original data, a product having a high frequency of use (e.g. for milks, the most widely consumed milk products among many milk products were selected to represent them) was purchased. Although we listed the processed beverages using the most recently released Korean National Health and Nutrition Examination Survey data at the time, there was a more than two years' difference between sampling for mineral analysis and the national survey. Therefore, at the time of purchase, the products being sold in the retail stores were included as final 91 samples. The beverages were purchased at retail stores such as convenience stores and supermarkets in Seoul, Gyeonggi, Chungnam and Chungbuk of Korea in September 2014. Ultimately, a total of 91 products (6 fruit juices, 6 fruit beverages, 11 carbonated beverages, 3 sports drinks, 6 caffeinated beverages, 14 alcoholic beverages, 16 mixed beverages, 6 teas, 5 natural mineral water, 10 milks, 5 fermented milks and 3 soymilks) were collected for analysis.

Nutrient content evaluation based on labels

For each product, selling price, product name, beverage category and volume (in millilitres) on the product label were recorded. The price of the beverages was converted from Korean wons to US dollars using the current exchange rate. Values of energy (in kilojouls), carbohydrate, sugar, protein and fat (in grams) were recorded only for nutrition-labelled products ($n = 72$). Energy content for alcoholic beverages ($n = 14$) was calculated from the labelled alcohol content (1 g alcohol = 29.31 kJ).

Mineral analysis of beverage products

Concentration of minerals in the beverage sample was analysed using inductively coupled plasma optical emission spectroscopy (ICP-OES) using the instrument Optima 5300 DV 9 (Perkin Elmer, Waltham, Massachusetts, USA). Beverage samples were prepared for analysis by mixing well and 5-fold diluting with 1% nitric acid. To measure mineral concentration in the beverage samples, calibration standard solutions were prepared by diluting the stock standard solution (Kanto Chemical, Tokyo, Japan) with 1% nitric acid. The ICP-OES system was operated at 1150 W forward power with a plasma flow of 8 $l\cdot min^{-1}$, sample uptake rate of 817 mHz, auxiliary gas flow rate of 0.2 $l\cdot min^{-1}$ and nebulizer gas flow rate of 0.8 $l\cdot min^{-1}$ with perfluoroalkoxy nebulizer. The analytical wavelengths used were 766.490 nm for potassium, 317.933 nm for calcium, 285.213 nm for magnesium and 249.677 nm for boron. The relative standard deviation was within 2–3 % for each sample.

Nutritional assessment of calcium, potassium and magnesium from beverages

The contribution rate of calcium, potassium and magnesium from 200 ml, in general one serving size of beverage, to *DRI*s for Koreans was evaluated. *DRI* used was the daily *RI* for male adolescents of 15–18 years of age, corresponding to a high school student [18].

Statistical analysis

Means and standard deviations were calculated for all variables. One-way ANOVA test was used to analyse the differences among the beverage groups and a post hoc analysis was performed using Duncan's multiple range test. All statistical analyses were performed using the program SAS Ver. 9.4 (SAS Institute, Cary, North Carolina, USA). The level of statistical significance was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

High consumption of beverages has become an important health and nutritional issue in many countries. Therefore, it is important to establish beverage intake guidelines based on the nutritional value of beverages. While all beverages support hydration by virtue of their high water content, many also supply energy and various components such as sugars, caffeine, alcohol and minerals.

Comparing 91 beverages, the selling price per 100 ml was on average 0.45 dollars, being highest for alcoholic beverages (0.75 dollars), while lowest for natural mineral waters (0.14 dollars). The energy content of nutrition-labelled beverages was on average 207.75 kJ, ranging from 31.40 kJ for teas to 314.97 kJ for fermented milks. The sugar content was on average 8.41 g, being highest in fruit juices (12.01 g), followed by sports drinks (11.04 g), fermented milks (10.29 g) and fruit beverages (10.27 g). The average concentration per 100 ml of carbohydrates, protein and fat was 9.67 g, 0.89 g and 0.61 g, respectively (Tab. 1).

Our main findings were that fermented milks, milks and soymilks had a high concentration

Tab. 1. Selling price and general composition of processed beverages sold in Korea.

Type of beverage	*n*	Price (US dollars)	Energy [kJ]	Carbohydrate [g]	Sugar [g]	Protein [g]	Fat [g]
Fruit juices	6	0.46 ± 0.03^{ab}	209.63 ± 52.25^{abcd}	13.56 ± 4.55^{a}	12.01 ± 4.45^{a}	1.91 ± 3.57^{a}	0.10 ± 0.13^{c}
Fruit beverages	6	0.36 ± 0.13^{bc}	192.09 ± 22.11^{bcd}	11.26 ± 1.63^{ab}	10.27 ± 2.21^{a}	0.19 ± 0.28^{b}	0.00 ± 0.00^{c}
Carbonated beverages	11	0.38 ± 0.15^{bc}	142.64 ± 92.61^{d}	8.69 ± 5.60^{ab}	8.52 ± 5.50^{ab}	0.04 ± 0.12^{b}	0.00 ± 0.00^{c}
Sports drinks	3	0.29 ± 0.01^{bc}	189.08 ± 110.82^{bcd}	11.54 ± 7.04^{ab}	11.04 ± 7.36^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}
Caffeinated beverages	6	0.61 ± 0.13^{ab}	177.48 ± 63.60^{cd}	8.88 ± 2.70^{ab}	8.75 ± 2.76^{ab}	0.59 ± 0.72^{b}	0.50 ± 0.93^{c}
Alcoholic beverages	14	0.75 ± 0.47^{a}	306.47 ± 138.04^{a}	–	–	–	–
Mixed beverages	16	0.37 ± 0.17^{bc}	157.67 ± 74.19^{d}	10.72 ± 5.00^{ab}	7.95 ± 4.64^{ab}	0.02 ± 0.06^{b}	0.08 ± 0.32^{c}
Teas	6	0.30 ± 0.05^{bc}	31.40 ± 52.54^{e}	1.85 ± 3.02^{c}	1.63 ± 2.60^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}
Natural mineral water	5	0.14 ± 0.04^{c}	–	–	–	–	–
Milks	10	0.41 ± 0.128^{bc}	278.38 ± 58.99^{abc}	9.58 ± 2.76^{ab}	9.11 ± 2.60^{ab}	2.51 ± 0.57^{a}	2.02 ± 1.10^{b}
Fermented milks	5	0.59 ± 0.28^{ab}	314.97 ± 110.95^{a}	13.34 ± 2.78^{a}	10.29 ± 2.20^{a}	2.56 ± 1.07^{a}	1.60 ± 1.46^{b}
Soymilks	3	0.38 ± 0.17^{bc}	297.47 ± 68.79^{ab}	6.14 ± 2.90^{bc}	4.39 ± 2.13^{bc}	3.16 ± 0.00^{a}	3.68 ± 0.53^{a}
Total beverages	91	0.45 ± 0.27	207.75 ± 115.14	9.67 ± 4.93	8.41 ± 4.58	0.89 ± 1.53	0.61 ± 1.15

Values per 100 ml of beverage are given. Data represent mean ± standard deviation. Different capital letters in a column indicate significant difference calculated by Duncan's multiple range test at $\alpha = 0.05$ (a > b > c > d).
n – number of samples.

Tab. 2. Mineral content in processed beverages sold in Korea.

Type of beverage	*n*	Ca [mg]	K [mg]	Mg [mg]	B [μg]
Fruit juices	6	12.55 ± 22.47 cd	31.70 ± 72.07 b	3.75 ± 3.44 c	131.87 ± 99.49 ab
Fruit beverages	6	2.35 ± 1.68 d	20.21 ± 47.38 b	1.63 ± 1.59 cd	16.62 ± 37.53 d
Carbonated beverages	11	2.35 ± 2.57 d	0.21 ± 0.27 b	0.37 ± 0.27 d	16.40 ± 9.98 d
Sports drinks	3	1.31 ± 1.13 d	1.25 ± 0.28 b	0.46 ± 0.40 d	45.27 ± 9.85 cd
Caffeinated beverages	6	14.61 ± 19.50 cd	50.42 ± 57.62 b	4.15 ± 3.62 c	18.57 ± 20.90 d
Alcoholic beverages	14	3.92 ± 3.77 d	26.88 ± 22.69 b	3.61 ± 2.65 c	102.01 ± 121.59 abc
Mixed beverages	16	2.81 ± 3.32 d	2.99 ± 9.21 b	0.52 ± 0.38 d	27.63 ± 25.84 cd
Teas	6	0.03 ± 0.06 d	0.29 ± 0.14 b	0.27 ± 0.08 d	13.47 ± 12.79 d
Natural mineral water	5	0.65 ± 0.59 d	0.01 ± 0.01 b	0.20 ± 0.10 d	15.18 ± 12.98 d
Milks	10	59.99 ± 31.54 b	149.63 ± 35.64 a	8.24 ± 2.04 b	42.60 ± 11.38 cd
Fermented milks	5	99.38 ± 50.69 a	169.37 ± 103.64 a	9.12 ± 5.23 b	80.74 ± 49.76 bcd
Soymilks	3	28.67 ± 27.88 c	161.37 ± 13.22 a	13.83 ± 3.86 a	166.07 ± 25.24 a
Total beverages	91	16.41 ± 31.91	42.56 ± 69.21	3.23 ± 4.11	50.72 ± 70.78

Values per 100 ml of beverage are given. Data represent mean ± standard deviation. Different capital letters in a column indicate significant difference calculated by Duncan's multiple range test at $\alpha = 0.05$ (a > b > c > d).
n – number of samples.

of calcium, potassium and magnesium. In the beverage products per 100 ml, the calcium concentration was highest at 99.38 mg in fermented milks, followed by milks (59.99 mg) and soymilks (28.67 mg). The potassium concentration was highest at 169.37 mg in fermented milks, followed by soymilks (161.37 mg) and milks (149.63 mg). The magnesium concentration was highest in soymilks (13.83 mg), followed by fermented milks (9.12 mg) and milks (8.24 mg). The boron concentration was highest at 166.07 μg in soymilks, followed by fruit juices (131.87 μg) and alcoholic beverages (102.01 μg; Tab. 2).

Tab. 3 shows the contribution rate of calcium, potassium and magnesium to *DRI*, based on a male high school student's daily consumption of 200 ml of beverage. The rank of beverages contributing to mineral intake was fermented milks (22.1 %), milks (13.3 %) and soymilks (6.4 %) for calcium; fermented milks (9.7 %), soymilks (9.2 %) and milks (8.6 %) for potassium; and soymilks (6.9 %), fermented milks (4.6 %) and milks (4.1 %) for magnesium. Abundant in milk and fermented milk, calcium not only plays a basic role in bone formation and remodelling, but also plays an important role in regulating various vital functions such as blood coagulation, neurotransmission, as well as muscle contraction and relaxation. Long-term calcium consumption affects the maximum bone mineral density (*BMD*) during the growth period, so maintaining a good calcium nutritional status from childhood up to the age of 35 is important to maintain a proper level of *BMD* in the skeleton for the rest of one's life. The calcium intake in Korean adolescents is low and the proportion of adolescents with calcium intake below the estimated average requirement is 84.1 %, which is surprisingly the highest among the entire life cycle groups [21].

Milk is high in calcium and it also contains lactose, which increases calcium absorption, so it is an ideal source of calcium for improving *BMD* during the growth period of humans. Based on this study, fermented milks also have a higher concentration of calcium, potassium and magnesium per 100 ml than other beverages, offering greater nutritional value. The availability of health-promoting components including high-quality proteins, bioactive compounds and vitamins increases during the fermentation process [22]. Potassium is the main electrolyte in the intracellular fluid and maintains normal osmotic pressure along with sodium ions, thus maintaining water balance in the body. Potassium also maintains an acid-base equilibrium with sodium and hydrogen ions. Because potassium is closely related to sodium and counteracts with sodium, potassium consumption is known to have a negative correlation with blood pressure in adolescents [23]. As noted above, the importance of potassium has been suggested in the preventive aspect for controlling blood pressure from the beginning of the life cycle, but the intake rate of potassium compared to the adequate intake (*AI*) in Korean adolescents (12 to 18 years old) was only 72.9 %, the lowest of the all life cycle [21]. The results of this study showed that the potassium amount in one serving of milk (200 ml), fermented milk or soymilk can provide 9~10 % of *AI* of potassium in male adolescents (Tab. 3). Therefore, among various beverages, milk, fermented milk and soymilk could be recommended for potassium nutrition in male adolescents as well as to prevent hypertension and heart disease in later life.

Magnesium plays a key role in the homeostasis of the skeleton and minerals and has a direct impact on formation and growth of bone hydroxyapatite crystals as well as on the function of skeletal cells [24]. Hence, adequate magnesium intake is highly required for normal skeletal growth during the growth period. According to Gou et al. [25], magnesium intake in adolescents showed a significantly positive relationship with femoral neck *BMD*. Dietary intake of magnesium from milk demonstrated a significant association with lumbar *BMD* in female adolescents [26]. The lack of previous studies on magnesium intake in Korean adolescents did not allow direct comparison of the current study results. However, Kim et al. [27] reported that women in their early 20s have insufficient magnesium intake, which was only 63 % of *RI* for magnesium, and that magnesium intake from milk was 6.39 mg per day, which was 3.4 % of total magnesium intake. In line with the knowledge that magnesium is largely contained in plant foods such as legumes [28], the study results showed the highest magnesium concentration in soymilk. Accordingly, adequate intake of magnesium is recommended through soymilk and milk for skeletal health in adolescents.

Boron is considered a trace element that is vital to plant growth and development. In bone metabolism, boron interacts with calcium, magnesium and vitamin D, and substantially contributes to bone mineral acquisition and skeletal structure formation [29]. Results of the present study are in line with those of a previous study, which analysed the concentration of boron in commonly consumed foods in Korea [30], finding the highest boron content in soymilk (1 833.1 $\mu g \cdot kg^{-1}$) followed by fruit juices (156.4~1 756.4 $\mu g \cdot kg^{-1}$), milk (357.0 $\mu g \cdot kg^{-1}$) and coffee drinks (308.3 $\mu g \cdot kg^{-1}$). To date, very few studies have evaluated boron intake in children and adolescents [31]. Considering boron functionality in skeletal health and the restrictions on alcoholic beverage consumption despite its high boron concentration (1 020.1 $\mu g \cdot kg^{-1}$), adolescents are encouraged to consume soymilk and fruit juice for boron intake.

With regard to the calcium, potassium and magnesium concentration in each beverage type in this study, caffeinated beverages were found to have a relatively high mineral concentration, following the most highly ranked beverage types for mineral concentration: milks, fermented milks and soymilks. Caffeinated beverages classified in this study included coffee, café latte (coffee with milk) and energy drinks. Therefore, a relatively high calcium concentration in caffeinated beverage group was likely due to the milk in café latte. Although the mineral composition of caffeinated beverages determined in this study seems to offer a positive effect, such as a relatively high concentration of calcium, potassium and magnesium, it should be carefully considered what kind of beverages were contained in this group, to-

Tab. 3. The contribution rate of minerals in processed beverages sold in Korea to reference intake.

Type of beverage	*n*	Contribution to reference intake		
		Ca [%]	K [%]	Mg [%]
Fruit juices	6	2.8 ± 5.0 cd	1.8 ± 4.1 b	1.9 ± 1.7 c
Fruit beverages	6	0.5 ± 0.4 d	1.2 ± 2.7 b	0.8 ± 0.8 cd
Carbonated beverages	11	0.5 ± 0.6 d	0.0 ± 0.0 b	0.2 ± 0.1 d
Sports drinks	3	0.3 ± 0.2 d	0.1 ± 0.0 b	0.2 ± 0.2 d
Caffeinated beverages	6	3.3 ± 4.3 cd	2.9 ± 3.3 b	2.1 ± 1.8 c
Alcoholic beverages	14	0.9 ± 0.8 d	1.5 ± 1.3 b	1.8 ± 1.3 c
Mixed beverages	16	0.6 ± 0.7 d	0.2 ± 0.5 b	0.3 ± 0.2 d
Teas	6	0.0 ± 0.0 d	0.0 ± 0.0 b	0.1 ± 0.0 d
Natural mineral water	5	0.1 ± 0.1 d	0.0 ± 0.0 b	0.1 ± 0.1 d
Milks	10	13.3 ± 7.0 b	8.6 ± 2.0 a	4.1 ± 1.0 b
Fermented milks	5	22.1 ± 11.3 a	9.7 ± 5.9 a	4.6 ± 2.6 b
Soymilks	3	6.4 ± 6.2 c	9.2 ± 0.8 a	6.9 ± 1.9 a
Total beverages	91	3.7 ± 7.1	2.4 ± 3.9	1.6 ± 2.1

Values per 200 ml of beverage are given. Data represent mean ± standard deviation. Reference intake means adequate intake for K (3 500 mg) and recommended intake for Ca (900 mg) and Mg (400 mg) of 15–18 aged male adolescents [19]. Different capital letters in a column indicate significant difference calculated by Duncan's multiple range test at $\alpha = 0.05$ (a > b > c > d). *n* – number of samples.

gether with the aspect of high sugar concentration and the stimulant effects of caffeine.

Several beverage intake studies focused on SSB in children and adolescents [32, 33]. SSB provide energy, so the consumption of these beverages has become a major energy contributor to modern diets and has been linked to health problems such as excessive weight gain, diabetes, metabolic syndrome or dental caries [9, 34, 35]. Considering the increase in consumption of SSB by children and adolescents due to marketing by suppliers, this study evaluated the mineral concentration in beverage products per price and energy. Comparing cost effectiveness of mineral content per one dollar, regarding the calcium content it was highest for fermented milks (177.98 mg), followed by milks (148.70 mg) and soymilks (97.72 mg); regarding the potassium content it was highest for soymilks (474.71 mg), followed by milks (382.55 mg) and fermented milks (283.43 mg); regarding the magnesium content it was highest for soymilks (42.13 mg), followed by milks (20.74 mg) and fermented milks (15.94 mg); regarding the boron content it was highest for soymilks (0.48 mg), followed by fruit juices (0.29 mg) and mixed beverages (0.28 mg; Tab. 4).

The mineral content per 418.68 kJ (100 kcal) of energy is shown in Tab. 5. The calcium content was highest in fermented milks (125.19 mg), followed by milks (87.82 mg) and soymilks (40.59 mg). The potassium content was highest in soymilks (232.05 mg), followed by milks (230.14 mg) and fermented milks (204.97 mg). The magnesium content was highest in soymilks (19.32 mg), followed by milks (12.57 mg) and fermented milks (11.22 mg). The boron content was highest in fruit juices (0.29 mg), followed by soymilks (0.25 mg) and mixed beverages (0.15 mg). These results regarding the minerals consumed per unit price or energy of the beverage were also high in milks, soymilks, fermented milks and fruit juices. An interesting result was that the mineral content consumed per unit price or energy of the beverage was low for SSB such as carbonated beverages, fruit beverages or sports drinks. Our results indicated that SSB are not desirable in terms of mineral nutrition for children and adolescents, and that they are high-calorie contributors as well.

This study has some limitations, in particular, the nutritional evaluation of minerals focusing on calcium, potassium, magnesium and boron was performed primarily on beverages commonly sold in Korea, but the limited number of samples of 91 is not fully sufficient to represent the entire market offer of beverages. If the number of samples of the beverages to be analysed was greater, it would be necessary to evaluate the mineral concentration using a more detailed classification. In addition, further research can be suggested to evaluate the bioavailability of minerals contained in beverages, as mineral bioavailability may vary with the beverage type and with other components contained in the beverages. Despite these limitations, at a time when consumption of processed beverages is increasing, comparative evaluation of various beverages through various aspects (e.g. concentration, economic value, or nutritional density) of minerals, which have high nutritional importance but had not been assessed, makes sense. Based on this approach, nutritional evaluation of

Tab. 4. Mineral content with respect to price of processed beverages sold in Korea.

Type of beverage	*n*	Ca [mg]	K [mg]	Mg [mg]	B [mg]
Fruit juices	6	25.78 ± 44.88 ^{c}	64.04 ± 144.54 ^{d}	7.95 ± 6.90 ^{c}	0.29 ± 0.21 ^{ab}
Fruit beverages	6	7.07 ± 5.16 ^{c}	44.21 ± 101.05 ^{d}	4.56 ± 3.96 ^{c}	0.04 ± 0.08 ^{b}
Carbonated beverages	11	7.03 ± 9.26 ^{c}	0.64 ± 0.90 ^{d}	1.05 ± 0.91 ^{c}	0.04 ± 0.02 ^{b}
Sports drinks	3	4.42 ± 3.84 ^{c}	4.29 ± 1.00 ^{d}	1.57 ± 1.34 ^{c}	0.15 ± 0.03 ^{ab}
Caffeinated beverages	6	22.39 ± 28.71 ^{c}	75.32 ± 85.38 ^{d}	6.19 ± 4.89 ^{c}	0.03 ± 0.03 ^{b}
Alcoholic beverages	14	8.82 ± 12.70 ^{c}	38.79 ± 27.65 ^{d}	6.74 ± 7.41 ^{c}	0.15 ± 0.17 ^{ab}
Mixed beverages	16	29.53 ± 69.95 ^{c}	11.07 ± 29.08 ^{d}	3.83 ± 7.33 ^{c}	0.28 ± 0.65 ^{ab}
Teas	6	0.12 ± 0.21 ^{c}	0.94 ± 0.34 ^{d}	0.90 ± 0.25 ^{c}	0.01 ± 0.01 ^{b}
Natural mineral water	5	5.08 ± 4.39 ^{c}	0.06 ± 0.03 ^{d}	1.34 ± 0.53 ^{c}	0.11 ± 0.08 ^{ab}
Milks	10	148.70 ± 79.25 ^{ab}	382.55 ± 114.25 ^{b}	20.74 ± 5.08 ^{b}	0.10 ± 0.03 ^{ab}
Fermented milks	5	177.98 ± 58.25 ^{a}	283.43 ± 91.81 ^{c}	15.94 ± 5.76 ^{b}	0.14 ± 0.06 ^{cb}
Soymilks	3	97.72 ± 99.71 ^{b}	474.71 ± 188.27 ^{a}	42.13 ± 22.53 ^{a}	0.48 ± 0.18 ^{a}
Total beverages	91	40.72 ± 71.57	93.56 ± 158.98	7.80 ± 10.72	0.15 ± 0.30

Values per 1 US dollar of beverage are given. Data represent mean ± standard deviation. Different capital letters in a column indicate significant difference calculated by Duncan's multiple range test at $\alpha = 0.05$ (a > b > c > d).
n – number of samples.

Tab. 5. Mineral content with respect to energy value of processed beverages sold in Korea.

Type of beverage	*n*	Ca [mg]	K [mg]	Mg [mg]	B [mg]
Fruit juices	6	23.41 ± 40.04^{cd}	57.64 ± 129.44^{bc}	7.33 ± 5.94^{bcd}	0.29 ± 0.21
Fruit beverages	6	5.53 ± 4.52^{cd}	45.59 ± 106.56^{bc}	3.84 ± 3.89^{cd}	0.04 ± 0.08
Carbonated beverages	11	5.81 ± 5.48^{cd}	0.56 ± 0.64^{c}	0.90 ± 0.59^{d}	0.04 ± 0.03
Sports drinks	3	4.49 ± 4.11^{cd}	3.31 ± 1.76^{c}	1.58 ± 1.41^{d}	0.13 ± 0.09
Caffeinated beverages	6	27.73 ± 32.85^{cd}	139.18 ± 168.06^{ab}	9.57 ± 6.93^{bc}	0.06 ± 0.10
Alcoholic beverages	14	6.59 ± 6.42^{cd}	43.71 ± 34.72^{bc}	6.76 ± 6.12^{bcd}	0.14 ± 0.16
Mixed beverages	16	9.96 ± 11.97^{cd}	6.47 ± 15.57^{c}	2.86 ± 5.78^{cd}	0.15 ± 0.28
Teas*	2	0.00 ± 0.00^{d}	2.13 ± 0.62^{c}	1.84 ± 1.02^{d}	0.01 ± 0.01
Milks	10	87.82 ± 45.05^{b}	230.14 ± 56.63^{a}	12.57 ± 2.83^{b}	0.07 ± 0.02
Fermented milks	5	125.19 ± 32.72^{a}	204.97 ± 81.22^{a}	11.22 ± 3.81^{b}	0.10 ± 0.03
Soymilks	3	40.59 ± 43.26^{c}	232.05 ± 32.08^{a}	19.32 ± 1.34^{a}	0.25 ± 0.08
Total beverages	82	28.83 ± 43.58	78.62 ± 110.21	6.59 ± 6.48	0.12 ± 0.17

Values per 418.68 kJ (100 kcal) of beverage are given. Data represent mean ± standard deviation. Different capital letters in a column indicate significant difference calculated by Duncan's multiple range test at $\alpha = 0.05$ (a > b > c > d).
* – natural mineral water ($n = 5$) and tea ($n = 4$) are excluded; *n* – number of samples.

more beverages and processed foods is required to expand the knowledge on a wider variety of nutritionally important minerals in the future.

CONCLUSIONS

Dairy milk, soymilk, and fruit juices had greater value in mineral nutrition such as calcium, potassium, magnesium and boron in terms of concentration, cost effectiveness and nutritional density. Although these beverages are well known to be health-promoting, their nutritional value as an important mineral contributor should also be highlighted to adolescents because of their high consumption of beverages and the nutritional importance of various minerals.

REFERENCES

1. Lee, H. S. – Duffey, K. J. – Popkin, B. M.: South Korea's entry to the global food economy: shifts in consumption of food between 1998 and 2009. Asia Pacific Journal of Clinical Nutrition, *21*, 2012, pp. 618–629. ISSN: 0964-7058.
2. Korea Health Statistics 2018: The Korea National Health and Nutrition Examination Survey (KNHANES VII-3). Cheongju : Korea Centers for Disease Control and Prevention, 2019. In Korean.
3. Gibson, S. – Shirreffs, S. M.: Beverage consumption habits "24/7" among British adults: Association with total water intake and energy intake. Nutrition Journal, *12*, 2013, pp. 9. DOI: 10.1186/1475-2891-12-9.
4. Szabo de Edelenyi, F. – Druesne-Pecollo, N. – Arnault, N. – González, R. – Buscail, C. – Galan, P.: Characteristics of beverage consumption habits among a large sample of French adults: Associations with total water and energy intakes. Nutrients, *8*, 2016, article 627. DOI: 10.3390/nu8100627.
5. Özen, A. E. – Bibiloni, M. D. M. – Bouzas, C. – Pons, A. – Tur, J. A.: Beverage consumption among adults in the Balearic Islands: Association with total water and energy intake. Nutrients, *10*, 2018, article 1149. DOI: 10.3390/nu10091149.
6. Armfield, J. M. – Spencer, A. J. – Roberts-Thomson, K. F. – Plastow, K.: Water fluoridation and the association of sugar-sweetened beverage consumption and dental caries in Australian children. American Journal of Public Health, *103*, 2013, pp. 494–500. DOI: 10.2105/AJPH.2012.300889.
7. Malik, V. S. – Schulze, M. B. – Hu, F. B.: Intake of sugar-sweetened beverages and weight gain: a systematic review. The American Journal of Clinical Nutrition, *84*, 2006, pp. 274–288. DOI: 10.1093/ajcn/84.1.274.
8. Ebbeling, C. B. – Feldman, H. A. – Chomitz, V. R. – Antonelli, T. A. – Gortmaker, S. L. – Osganian, S. K. – Ludwig, D. S.: A randomized trial of sugar sweetened beverages and adolescent body weight. The New England Journal of Medicine, *367*, 2012, pp. 1407–1416. DOI: 10.1056/NEJMoa1203388.
9. Malik, V. S. – Popkin, B. M. – Bray, G. A. – Després, J. P. – Willett, W. C. – Hu, F. B.: Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. Diabetes Care, *33*, 2010, pp. 2477–2483. DOI: 10.2337/dc10-1079.
10. Dietary Guidelines for Americans 2015–2020. 8th ed. Washington D. C.: U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015. ISBN: 9780160934650. <https://health.gov/sites/default/files/2019-09/2015-2020_Dietary_Guidelines.pdf>
11. Silver, L. D. – Ng, S. W. – Ryan-Ibarra, S. – Taillie, L. S. – Induni, M. – Miles, D. R. – Poti, J. M. – Popkin, B. M.: Changes in prices, sales, consumer

spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: A before-and-after study. PLoS Medicine, *14*, 2017, e1002283. DOI: 10.1371/journal.pmed.1002283.

12. Bleich, S. N. – Vercammen, K. A. – Koma, J. W. – Li, Z.: Trends in beverage consumption among children and adults, 2003–2014. Obesity, *26*, 2018, pp. 432–441. DOI: 10.1002/oby.22056.
13. Korea Health Statistics 2010: The Korea National Health and Nutrition Examination Survey (KNHANES V-1). Cheongju : Korea Centers for Disease Control and Prevention, 2011. In Korean.
14. Whelton, A. J. – Dietrich, A. M. – Burlingame, G. A. – Schechs, M. – Duncan, S. E.: Minerals in drinking water: impacts on taste and importance to consumer health. Water Science and Technology, *55*, 2007, pp. 283–291. DOI: 10.2166/wst.2007.190.
15. Stathopoulou, M. G. – Kanoni, S. – Papanikolaou, G. – Antonopoulou, S. – Nomikos, T. – Dedoussis, G.: Mineral intake. Progress in Molecular Biology and Translational Science, *108*, 2012, pp. 201–236. DOI: 10.1016/B978-0-12-398397-8.00009-5.
16. Larsson, S. C. – Virtamo, J. – Wolk, A.: Potassium, calcium, and magnesium intakes and risk of stroke in women. American Journal of Epidemiology, *174*, 2011, pp. 35–43. DOI: 10.1093/aje/kwr051.
17. Kim, M.-H. – Choi, M.-K.: Seven dietary minerals (Ca, P, Mg, Fe, Zn, Cu, and Mn) and their relationship with blood pressure and blood lipids in healthy adults with self-selected diet. Biological Trace Element Research, *153*, 2013, pp. 69–75. DOI: 10.1007/s12011-013-9656-1.
18. Dietary Reference Intakes for Koreans. Seoul : The Korean Nutrition Society, 2015. ISBN: 978-89-94160-39-9. In Korean.
19. Korean Food Standards Codex. Cheongju : Ministry of Food and Drug Safety, 2018. In Korean.
20. The Korea National Health and Nutrition Examination Survey (KNHANES V-1~3) raw data. Cheongju : Korea Centers for Disease Control and Prevention, 2013. In Korean.
21. Korea Health Statistics 2016: The Korea National Health and Nutrition Examination Survey (KNHANES VII-1). Cheongju : Korea Centers for Disease Control and Prevention, 2017. In Korean.
22. Rezac, S. – Kok, C. R. – Heermann, M. – Hutkins, R.: Fermented foods as a dietary source of live organisms. Frontiers in Microbiology, *9*, 2018, article 1785. DOI: 10.3389/fmicb.2018.01785.
23. Chmielewski, J. – Carmody, J. B.: Dietary sodium, dietary potassium, and systolic blood pressure in US adolescents. Journal of Clinical Hypertension, *19*, 2017, pp. 904–909. DOI: 10.1111/jch.13014.
24. Viljakainen, H. T.: Factors influencing bone mass accrual: focus on nutritional aspects. Proceedings of the Nutrition Society, *75*, 2016, pp. 415–419. DOI: 10.1017/S0029665116000252.
25. Gou, G.-H. – Tseng, F.-J. – Wang, S.-H. – Chen, P.-J. – Shyu, J.-F. – Pan, R.-Y.: Nutritional factors associated with femoral neck bone mineral density in children and adolescents. BMC Musculoskeletal Disorders, *20*, 2019, article 520. DOI: 10.1186/s12891-019-2901-9.
26. Esterle, L. – Sabatier, J. P. – Guillon-Metz, F. – Walrant-Debray, O. – Guaydier-Souquieres, G. – Jehan, F. – Garabedian, M.: Milk, rather than other foods, is associated with vertebral bone mass and circulating IGF-1 in female adolescents. Osteoporosis International, *20*, 2009, article 567. DOI: 10.1007/s00198-008-0708-x.
27. Kim, M.-H. – Yeon, J.-Y. – Choi, M.-K. – Bae, Y. J.: Evaluation of magnesium intake and its relation with bone quality in healthy young Korean women. Biological Trace Element Research, *144*, 2011, pp. 109–117. DOI: 10.1007/s12011-011-9044-7.
28. Bae, Y.-J. – Kim, M.-H. – Choi, M.-K.: Analysis of magnesium contents in commonly consumed foods and evaluation of its daily intake in Korean independent-living subjects. Biological Trace Element Research, *135*, 2010, pp. 182–199. DOI: 10.1007/s12011-009-8511-x.
29. Meacham, S. L. – Taper, L. J. – Volpe, S. L.: Effect of boron supplementation on blood and urinary calcium, magnesium, and phosphorus, and urinary boron in athletic and sedentary women. The American Journal of Clinical Nutrition, *61*, 1995, pp. 341–345. DOI: 10.1093/ajcn/61.2.341.
30. Choi, M.-K. – Jun, Y.-S.: Analysis of boron content in frequently consumed foods in Korea. Biological Trace Element Research, *126*, 2008, pp. 13–26. DOI: 10.1007/s12011-008-8179-7.
31. Pieczyńska, J. – Borkowska-Burnecka, J. – Biernat, J. – Grajeta, H. – Zyrnicki, W. – Zechałko-Czajkowska, A.: Boron content in daily meals for preschool children and school youth. Biological Trace Element Research, *96*, 2003, pp. 1–8. DOI: 10.1385/BTER:96:1-3:1.
32. Kim, A. – Kim, J. – Kye, S.: Sugar-sweetened beverage consumption and influencing factors in Korean adolescents: based on the 2017 Korea Youth Risk Behavior Web-based Survey. Journal of Nutrition and Health, *51*, 2018, pp. 465–479. DOI: 10.4163/jnh.2018.51.5.465.
33. Kim, J. – Yun, S. – Oh, K.: Beverage consumption among Korean adolescents: data from 2016 Korea Youth Risk Behavior Survey. Nutrition Research and Practice, *13*, 2019, pp. 70–75. DOI: 10.4162/nrp.2019.13.1.70.
34. Hu, F. B. – Malik, V. S.: Sugar-sweetened beverages and risk of obesity and type 2 diabetes: epidemiologic evidence. Physiology and Behavior, *100*, 2010, pp. 47–54. DOI: 10.1016/j.physbeh.2010.01.036.
35. Marshall, T. A.: Preventing dental caries associated with sugar-sweetened beverages. Journal of the American Dental Association, *144*, 2013, pp. 1148–1152. DOI: 10.14219/jada.archive.2013.0033.

Received 3 May 2020; 1st revised 16 June 2020; 2nd revised 21 June 2020; accepted 3 August 2020; published online 8 August 2020.