Comparison of mineral content of bottled spring and mineral waters marketed in Turkey

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A B S T R A C T
Drinking water is the most indispensable substance for humans. Bottled drinking waters are preferred over tap water with the belief that they are more nutritious, better quality, more delicious and safe in terms of health. Therefore, the Turkish bottled (spring and mineral) water market has experienced a continuous growth since 2003, as in the whole world. This study focuses on comparing the common mineral cation calcium (Ca2+), magnesium (Mg2+) and sodium (Na+) content of twenty one popular bottled spring and mineral water brands marketed in Turkey by using an inductively coupled plasma optical emission spectrometry (ICP-OES). The average concentrations of Ca, Mg and Na analyzed in bottled spring and mineral water samples were found as 14.9, 24.1 and 8.2 mg/L and 147.9, 44.3 and 117.3 mg/L, respectively. This comparison confirms that bottled natural mineral water has better quality in terms of major nutrient minerals than bottled natural spring waters.

Keywords:
Bottled mineral water
Bottled spring water
Major nutrient
Sodium
Magnesium

Introduction

Drinking water, which has many important roles such as hydro-electrolytic, acid-base and thermal balance, dissolution, digestion, absorption and disposal of nutrients in consumed foods, is an essential food source for humans (Petraccia et al., 2006). However, the rapid increase in the population and the growth of human activities that can cause contamination significantly increase the demand for providing adequate and safe sources of drinking water.

The impressive increase in the consumption of bottled water worldwide is due to consumers’ concerns about increased water pollution and their objections to offensive flavors and odors such as chlorine and bacterial contamination from municipal water supplies (Güler, 2007). Another reason is the common belief that bottled mineral waters contain nutritious minerals and have beneficial therapeutic and medicinal influences (Seid et al., 2020). Bottled drinking water industries have been established to achieve this balance of supply and demand. Consequently, the bottled water global markets are constantly growing to meet the increase in demand and the search of quality drinking water. While the global average annual bottled drinking water (generally bottled natural mineral water) consumption per capita is 24.2 L, this value is 105 L in the European Union (Bityukova and Petersell, 2010). In 2020, Turkey’s bottled drinking water production reached to 10.5 × 10⁶ L and annual bottled drinking water consumption per capita is 126 L (SUDER, 2021). Although Turkey has a great potential for natural mineral waters, mineral water consumption in Turkey is significantly lower compared to the European Union (Mertoğlu et al., 2003). However, with the introduction of bottled natural fruit-flavored mineral waters in the market in 2002, bottled mineral water consumption per capita reached 7.6 L (Cemek et al., 2007; Gümüş et al., 2020).

Bottled drinking waters are supplied from many sources, such as aquifers, reservoirs, springs, and highly mineralized springs (Kurnaz et al., 2016; Al Aamri and Ali, 2017; Mutlu and Kurnaz, 2017; Mutlu and Kurnaz, 2018; Mutlu, 2019; Mutlu, 2021). The chemical composition of bottled spring and mineral waters depends on the local
geology of the source area and the geochemistry of rocks in contact with water (Daniele et al., 2019). Therefore, depending on their sources, bottled waters include different amounts of macro and microelements such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), etc. that significantly affect living organisms (Bertoldi et al., 2011; Koçzyk et al., 2019). Ca, Mg and Na are essential nutrients for human health. More than 99% of total body Ca is found in bones and teeth where it functions as an important structural element. The remaining body Ca functions in metabolism serves as a signal for vital physiological processes including blood clotting, vascular contraction, muscle contraction, blood clotting and nerve transmission (WHO, 2009). Mg is the fourth most abundant cation in the human body and the second most abundant cation in the intracellular fluid. Mg is a cofactor of about 350 cellular enzymes. Mg is needed for insulin sensitivity and normal vascular tone (WHO, 2009). Na is fundamental regulation of cell permeability and body fluids. Na deficiency is rare, but an excessive intake may be associated with high blood pressure (Quattrini et al., 2016). The ideal bottled water should be rich in Ca and Mg and have low Na content. However, no definite conclusions can be drawn concerning the possible association between Na in mineral water and the occurrence of hypertension but Na concentrations in excess of 200 mg L\(^{-1}\) may cause an unacceptable taste (Koçzyk et al., 2019).

While the concentrations of Ca, Mg and Na in bottled drinking water vary significantly from one source to another, mineral-rich drinking water may make significant contributions to the total intake of these nutrients in some populations or population subgroups (WHO, 2009). Therefore, bottled water should be supported by accurate information about their chemical composition. In particular, the chemical composition and related properties of mineral waters are not only important for health, but also for the promotion and advertising of these waters (Koçzyk et al., 2019). Up to now, many studies have focused on the chemical quality of bottled drinking and mineral waters consumed in various countries and Turkey (Mahajan et al., 2006; Cemek et al., 2007; Baba et al., 2008; Güler and Alpaslan, 2009; Cicchella et al., 2010; Cengiz et al., 2015; Dos Santos et al. 2016; Khandaker et al., 2017; Dippong et al., 2020; Todorović et al., 2020). However, the contents Ca, Mg and Na in bottled spring and mineral waters commercially sold in Turkey have not been compared. Having in mind the fact mentioned above, the purposes of the study is to: (1) analyze major minerals (Ca, Mg and Na) in forty-two bottled water (twenty-one springs and twenty-one minerals) brands commercially available on Turkish market and (2) compare the concentration of Ca, Mg and Na in these brands of bottled spring and mineral water.

Material and Methods

**Collection and Preparation of Bottled Water Samples**

In Turkey, most of the bottled natural mineral waters are sold in 0.2, 0.25 and 0.330 L volumes of metal screw-cap glass bottles, while bottled natural spring waters are sold in 0.5, 1.5 and 5 L plastic bottles made of polyethylene terephthalate (PET). Forty-two bottled water brands chosen for this study represent the highest selling and most consumed brands on daily basis by the Turkish population. Twenty-one brands of bottled spring water and twenty-one brands of bottled mineral water available on the Turkish market were purchased in randomly selected supermarkets in Ankara, the capital city of Turkey.

All bottled water samples were kept at room temperature until analysis and each water sample was opened in the laboratory. Each bottled spring water sample was filtered from microfilters so that no particles were left, and then it was taken into the analysis process without any process (Alzaridi and Kurnaz, 2020). Whereas each bottled mineral water sample was degassed by using an ultrasonic bath for 15 minutes at room temperature. All reagents used for analyses were of analytical grade.

**Instrumental Analysis**

The concentration of cations (Ca\(^{2+}\), Mg\(^{2+}\) and Na\(^+\)) were analyzed by the Spectroblue ICP–OES system equipped with Spectro’s proprietary ICP Analyzer Pro software in the Central Laboratory of Kastamonu University. Details of the ICP-OES system are given in the study performed by Alzaridi and Kurnaz (2020). The ICP-OES instrument was used at 1.2 kW plasma power and the gas flows in the auxiliary and nebulizer were maintained at 0.8 L min\(^{-1}\). Each of the measurements was set to repeat three-times. Calibration solutions were prepared by diluting the certified standard ICP TraceCert mix solutions containing 33 elements purchased from Sigma–Aldrich. Calibration of the ICP–OES system was carried out at the beginning of the measurements and the correlation coefficients were higher than 0.999 for all analytes.

**Results and discussion**

The concentrations of major cations analyzed in bottled spring or drinking water (BDW) samples and bottled mineral water (BMW) samples are given in Table 1 and Table 2, respectively. Frequency distributions of the concentrations of Ca, Mg and Na in BDW and BMW samples are given in Figure 1 and Figure 2, respectively. Table 3 compares the average concentration of these major cations analyzed in the studied BDW and BMW samples with those analyzed in BDW and BMW samples consumed in various countries.

It can be seen from Table 1 that the order of major minerals analyzed in the studied BDW samples is Mg > Ca > Na according to their average concentration values. As can be seen from Figure 1, the frequency distributions of the concentration of Ca and Na exhibit a log-normal distribution while the frequency distribution of the concentration of Mg exhibits non-normal distribution. The concentration of Ca varied from 1.9 to 31.9 mg/L with an average of 14.9 mg/L. The highest Ca concentration was analyzed in the BDW3 coded brand, the lowest Ca concentration was analyzed in the BDW15 coded brand. From Table 3, the average Ca content is higher than those analyzed in BDW samples consumed in Malaysia, Romania, Oman, Bangladesh, and South Korea while it is lower than those in BDW samples consumed in Chile, Germany, Croatia, Spain, Iran, and India. The concentration of Mg varied from 0.4 to 49.7 mg/L with an average of 24.1 mg/L. The highest Mg concentration was analyzed in the BDW14 coded brand, the lowest Mg concentration was analyzed in the BDW15 coded brand.
Table 1. Concentrations of major cations analyzed in bottled spring water samples

| Sample ID | Ca   | Mg   | Na   |
|-----------|------|------|------|
| BDW1      | 9.1  | 5.7  | 1.7  |
| BDW2      | 9.9  | 38.1 | 2.5  |
| BDW3      | 31.9 | 18.9 | 3.7  |
| BDW4      | 17.8 | 48.3 | 5.7  |
| BDW5      | 15.0 | 34.1 | 5.9  |
| BDW6      | 15.8 | 34.5 | 5.9  |
| BDW7      | 22.3 | 35.1 | 3.8  |
| BDW8      | 7.7  | 12.1 | 4.3  |
| BDW9      | 7.6  | 19.1 | 5.3  |
| BDW10     | 10.7 | 37.4 | 4.0  |
| BDW11     | 19.9 | 27.4 | 2.7  |
| BDW12     | 25.5 | 49.7 | 3.8  |
| BDW13     | 23.8 | 39.2 | 6.4  |
| BDW14     | 13.7 | 49.7 | 12.1 |
| BDW15     | 1.9  | 3.5  | 2.5  |
| BDW16     | 10.9 | 22.9 | 76.1 |
| BDW17     | 12.6 | 21.9 | 13.9 |
| BDW18     | 14.1 | 0.4  | 0.7  |
| BDW19     | 9.9  | 3.7  | 4.3  |
| BDW20     | 26.2 | 2.7  | 4.7  |
| BDW21     | 6.4  | 1.0  | 1.6  |

Average: 14.9 Ca, 24.1 Mg, 8.2 Na
Standard error: 1.7 Ca, 3.7 Mg, 4.3 Na
Median: 13.7 Ca, 22.9 Mg, 4.3 Na
Standard deviation: 7.6 Ca, 17.0 Mg, 15.9 Na
Kurtosis: -0.2 Ca, -1.4 Mg, 19.1 Na
Skewness: 0.6 Ca, 0.0 Mg, 4.3 Na
Min: 1.9 Ca, 0.4 Mg, 0.7 Na
Max: 31.9 Ca, 49.7 Mg, 76.1 Na

Table 2. Concentrations of major cations analyzed in bottled mineral water samples

| Sample ID | Ca   | Mg   | Na   |
|-----------|------|------|------|
| BMW1      | 190.8| 20.7 | 6.4  |
| BMW2      | 31.3 | 5.1  | 10.1 |
| BMW3      | 43.0 | 82.6 | 73.5 |
| BMW4      | 52.0 | 8.9  | 543.0|
| BMW5      | 65.4 | 24.7 | 640.4|
| BMW6      | 123.9| 3.7  | 3.8  |
| BMW7      | 22.9 | 4.3  | 23.2 |
| BMW8      | 198.8| 120.8| 217.5|
| BMW9      | 393.1| 30.1 | 12.0 |
| BMW10     | 177.6| 102.2| 104.8|
| BMW11     | 59.8 | 28.7 | 26.7 |
| BMW12     | 180.9| 34.7 | 18.5 |
| BMW13     | 131.0| 45.2 | 124.8|
| BMW14     | 175.5| 102.1| 105.5|
| BMW15     | 143.9| 82.1 | 86.0 |
| BMW16     | 302.7| 44.6 | 143.2|
| BMW17     | 102.0| 26.7 | 91.8 |
| BMW18     | 221.5| 82.8 | 80.7 |
| BMW19     | 8.9  | 1.4  | 4.4  |
| BMW20     | 189.8| 33.9 | 22.9 |
| BMW21     | 208.3| 45.8 | 125.0|

Average: 190.8 Ca, 44.3 Mg, 117.3 Na
Standard error: 21.2 Ca, 8.0 Mg, 36.7 Na
Median: 143.9 Ca, 33.9 Mg, 80.7 Na
Standard deviation: 97.0 Ca, 36.5 Mg, 168.4 Na
Kurtosis: 0.7 Ca, -0.6 Mg, 5.6 Na
Skewness: 0.7 Ca, 0.7 Mg, 2.4 Na
Min: 8.9 Ca, 1.4 Mg, 3.8 Na
Max: 393.1 Ca, 120.8 Mg, 640.4 Na
From Table 3, the average Mg content is higher than those analyzed in BDW samples consumed in all countries. The concentration of Na varied from 0.7 to 76.1 mg/L with an average of 8.2 mg/L. The highest Na concentration was analyzed in the BDW18 coded brand, the lowest Na concentration was analyzed in the BDW16 coded brand. From Table 3, the average Na content is higher than those analyzed in BDW samples consumed in Croatia, Malaysia, Romania, Bangladesh, and South Korea while it lower than those in BDW samples consumed in Chile, Germany, Spain, Iran, Oman, and India.
It can be seen from Table 2 that the order of major minerals analyzed in the studied BMW samples is Ca > Na > Mg according to their average concentration values. As can be seen from Figure 1, the frequency distributions of the concentration of Mg and Na exhibit a log-normal distribution while the frequency distribution of the concentration of Ca exhibits near-normal distribution. The concentration of Ca varied from 8.9 to 393.1 mg/L with an average of 143.9 mg/L. The highest Ca concentration was analyzed in the BMW9 coded brand, the lowest Ca concentration was analyzed in the BMW19 coded brand. The average concentration of Ca is approximately ten times higher than that analyzed in the studied BDW samples. From Table 3, the average Ca content is higher than those analyzed in BMW samples consumed in various countries. The concentration of Mg varied from 1.4 to 120.87 mg/L with an average of 44.3 mg/L. The highest Mg concentration was analyzed in the BMW8 coded brand, the lowest Mg concentration was analyzed in the BMW19 coded brand. The average concentration of Mg is approximately two times higher than that analyzed in the studied BDW samples. From Table 3, the average Mg content is higher than those analyzed in BMW samples consumed in all countries except for Slovenia. The concentration of Na varied from 3.8 to 640.4 mg/L with an average of 117.3 mg/L. The highest Na concentration was analyzed in the BMW5 coded brand, the lowest Na concentration was analyzed in the BMW6 coded brand. The average concentration of Na is approximately fourteen times higher than that analyzed in the studied BDW samples. From Table 3, the average Na content is higher than those analyzed in BMW samples consumed in all countries except for Estonia and Slovenia.

Conclusion

A comparison of the average values of the major minerals in the bottled spring and mineral waters revealed that the concentrations of Ca, Mg, and Na are 2 to 14 times higher in the bottled mineral waters compared to spring waters. This differentiation in average concentrations of major minerals is anticipated because natural mineral waters are mostly supplied from areas near geothermal regions with deep groundwater circulation patterns and recent tectonic/volcanic activity.

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