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

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ABSTRACT

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 (Ca^{2+}), magnesium (Mg^{2+}) 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.

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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 × 10^9 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; Kończyk 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 (Kończyk 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 intakes 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 (Kończyk 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	Concentration (mg/L)		
	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	24.1	8.2
Standard error	1.7	3.7	3.5
Median	13.7	22.9	4.3
Standard deviation	7.6	17.0	15.9
Kurtosis	-0.2	-1.4	19.1
Skewness	0.6	0.0	4.3
Min	1.9	0.4	0.7
Max	31.9	49.7	76.1

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

Sample ID	Concentration (mg/L)		
	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	143.9	44.3	117.3
Standard error	21.2	8.0	36.7
Median	143.9	33.9	80.7
Standard deviation	97.0	36.5	168.4
Kurtosis	0.7	-0.6	5.6
Skewness	0.7	0.7	2.4
Min	8.9	1.4	3.8
Max	393.1	120.8	640.4

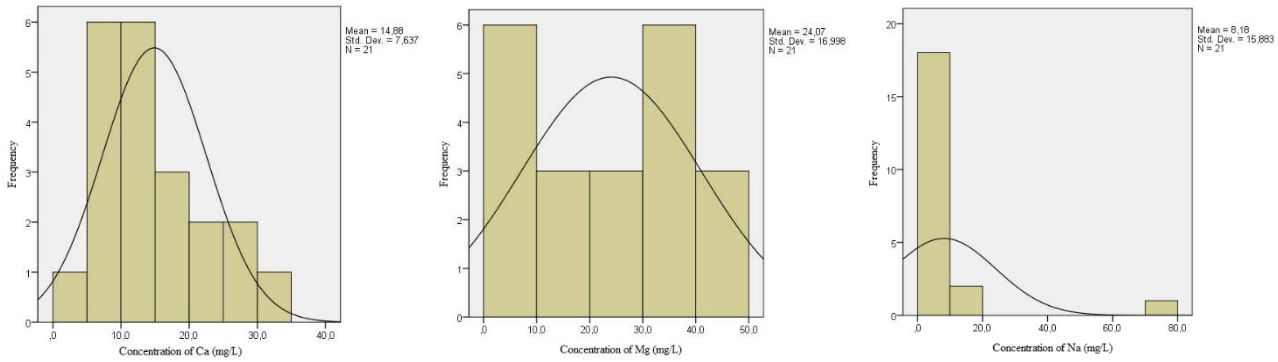

Figure 1. Frequency distributions of the concentrations of Ca, Mg and Na in the studied bottled spring waters

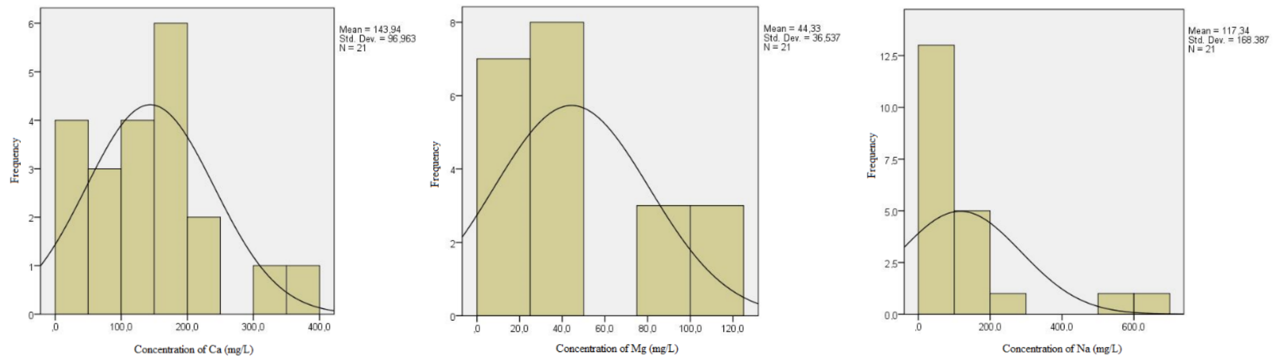

Figure 2. Frequency distributions of the concentrations of Ca, Mg and Na in the studied bottled mineral waters

Table 3. Comparison of the average concentration of major cations with the literature values

Water type	N	Origin	Ca	Mg	Na	Reference
BDW	10	Chile	36	8	25	Daniele et al., 2019
BDW	908	Germany	91	22	20	Birke et al., 2010
BDW	10	Croatia	57	17	3	Peh et al., 2010
BDW	13	Spain	42	14	45	Platikanov et al., 2017
BDW	20	Iran	33	12	17	Kermanshahi et al., 2010
BDW	10	Malaysia	0,4	0,3	0,7	Aris et al., 2013
BDW	14	Romania	4	4	2	Dippong et al., 2020
BDW	17	Oman	13	10	12	Al Aamri et al., 2017
BDW	17	India	17	8	23	Mahajan et al., 2006
BDW	14	Bangladesh	0.04	0.01	0.29	Rahman et al., 2017
BDW	35	South Korea	0.5	0.2	0.3	Bong et al., 2009
BDW	21	Turkey	15	24	8	This study
BMW	186	Italy	69	13	20	Cicchella et al., 2010
BMW	9	Malaysia	41	10	11	Khandaker et al., 2017
BMW	14	Egypt	20	8	31	Yousef, 2018
BMW	9	Serbia	46	22	33	Jankovic´ et al., 2012
BMW	86	British Isles	46	8	18	Smedley, 2010
BMW	47	Poland	82	26	44	Astel et al., 2014
BMW	5	Estonia	69	23	212	Bityukova and Petersell, 2010
BMW	21	Romania	107	27	47	Levei et al., 2016
BMW	571	EU	67	16	15	Bertoldi et al., 2011
BMW	9	Ethiopia	13	6	38	Seda et al., 2013
BMW	22	Nordic	6	11	12	Frengstad et al., 2010
BMW	53	Iran	50	12	8	Kermanshahi et al., 2010
BMW	35	Slovenia	120	104	218	Brenčič et al., 2010
BMW	21	Turkey	144	44	117	This study

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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