



Determination of major minerals in bottled natural fruit-flavored mineral water samples consumed in Turkey

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Abstract: Recently bottled mineral water has become very popular as a nutritional (mineral) supplement. In this study, the concentrations of some major minerals (Na, K, Ca, and Mg) in twenty-nine bottled natural fruit-flavored mineral water samples of ten commercially brands sold in Turkish markets were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) technique. The concentrations of Na, K, Ca, and Mg analysed in BNFM water samples varied from 11 to 2829 mg L⁻¹, 30 to 189 mg L⁻¹, 36 to 380 mg L⁻¹ and 17 to 104 mg L⁻¹, respectively. The results were compared with those obtained for natural mineral waters in the literature. Also, bottled natural fruit-flavored mineral water samples were classified according to their Ca, Mg, and Na content. Consequently, 38%, 31% 24%, and 24% of the studied water samples are calcium waters, magnesium waters, sodium waters, and waters suitable for the sodium diet respectively.

[Şeref Turhan. **Determination of major minerals in bottled natural fruit-flavored mineral water samples consumed in Turkey.** *Life Sci J* 2021;18(12):1-8]. ISSN 1097-8135 (print); ISSN 2372-613X (online). <http://www.lifesciencesite.com>. 1.doi:[10.7537/marslsj181221.01](https://doi.org/10.7537/marslsj181221.01).

Keywords: Bottled mineral water; Sodium, Magnesium, Calcium, Potassium, Macro mineral

1. Introduction

Natural mineral water containing different dissolved minerals has been used for treatment in spas and baths for thousands of years in Anatolia as well as in many parts of the world. Since the water-borne minerals such as calcium, magnesium, sodium, and potassium in the ionic form are easily absorbed by the gastrointestinal system natural mineral water is also consumed intensively as a drink beneficial to human health^[1]. Mineral water represents underground water that is naturally formed in suitable geological conditions at various depths of the earth's crust and is extracted to the earth by one or more sources spontaneously or by technical methods^[2]. Natural mineral water is defined with mineral content, residual elements, and other components and bottled directly at the source and protected against any contamination risks^[2]. Any bacteriological treatment for natural mineral waters is prohibited and no substance can be added, except for carbon dioxide^[3].

The consumption of bottled natural mineral waters has been greatly increasing over the last decades. The average annual consumption of bottled mineral water per capita in the European Union is 105 L^[54]. However, bottled mineral water consumption in Turkey is very low compared to European Union countries. In recent years, some companies have produced mineral waters with various fruit flavors to increase the consumption of bottled mineral water in Turkey. After fruit-flavored natural mineral waters were introduced on Turkish markets per capita mineral water consumption reached 7.6 L^[5].

About twenty mineral elements such as chloride (Cl⁻), fluoride (F⁻), calcium (Ca²⁺), potassium (K⁺), magnesium (Mg²⁺), sodium (Na⁺), copper (Cu²⁺), iron (Fe²⁺), manganese (Mn²⁺), zinc (Zn²⁺), etc. are required for humans. The mineral abundance in the human body is about 5% of body mass. The mineral elements required at a level higher than 100 mg per day are considered as macro elements such as Ca, K, Mg, Na, etc. Ca and Mg are needed for the bones and the health of the cardiovascular system. Na and K are in solution and important for the electrolyte balance. The mineral contents of bottled natural mineral waters vary significantly from one source to another depending upon the nature of the geological formations through the groundwater passed. Bottled natural mineral waters have been classified differently according to their mineral content. Each mineral water was named considering firstly, the common anion and secondly, the cation^[7]. According to Turkish legislation prepared by Ministry of Health, they classified as follows^[2]: calcium water (chloride content > 150 mg/L), magnesium water (magnesium content > 50 mg/L), sodium water (sodium content > 200 mg/L), water suitable for sodium diet (sodium content < 20 mg/L), etc. Therefore, bottled mineral waters should be supported by accurate information about their chemical composition. So far, many studies were performed to monitor the chemical quality of bottled mineral waters sold in the market in some countries^[8-20]. However, few studies were carried out to determine the chemical quality of bottled natural mineral waters consumed in Turkey^[21-26]. According to the author's literature research, no study was on the determination of major

minerals in bottled fruit-flavored mineral waters sold commercially in Turkey. Having all these in mind, the objective of this study is to determine the concentration of some major minerals (Ca, K, Mg, and Na) in bottled fruit-flavored mineral water samples consumed in Turkey by using an inductively coupled plasma-optical emission spectrometer (ICP-OES), compare the results with those obtained from similar studies in literature, and classify water samples according to their Ca, Mg and Na contents.

2. Material and methods

2.1 Collection and preparation of water samples

For this study, ten brands of commercially available bottled natural mineral water were chosen as the preferred popular brands throughout the country. A large part of the bottled natural mineral waters in Turkey is sold in a glass bottle with metal screw caps with volumes of 0.2 and 0.25 L. Twenty-nine bottled carbonated natural fruit-flavored mineral water samples were purchased from supermarkets in Turkey. These natural fruit-flavored mineral water samples were coded as BFMW to keep the brand names confidential (Table 1).

The bottled mineral water samples were kept at room temperature until analysis. Each water sample was opened in the laboratory and degassed by using an ultrasonic bath for 15 minutes at room temperature. All reagents used for analyses were of analytical grade. All dilutions were made by using ultrapure water ($18.2 \text{ M}\Omega \text{ cm}^{-1}$) supplied by a New Human Power I Scholar UV Water Purification System (Human Corporation, Seoul, Korea).

The water samples were prepared using the following procedure: Analytical portions were digested with a microwave digestion system (CEM MARS 6, USA) equipped with temperature and pressure control to $200 \text{ }^\circ\text{C}$ and 45 bar. 1 mL of aliquot each water sample was transferred into the digestion vessel and 10 mL of HNO_3 (67% v/v) was added to the aliquot. Before closing the vessel, the mixture was swirled slightly and the lid was tightly closed. The vessel was placed in a microwave oven and heated according to the digestion program. After the digestion, the sample solution was cooled to room temperature. The aliquot was transferred to a volumetric flask of 25 mL, 50 mL, and 100 mL and completed with ultrapure water. It is filtered through a microfilter so that no particles are left in it.

2.2 Calibration and instrumental analysis

The concentrations of major elements were analyzed by the Spectroblue ICP-OES system equipped with Spectro's proprietary ICP Analyzer Pro software making it easy to take full advantage of the instrument's simplified operation and analytical capabilities. The system delivers a resolution of 8 pm in the important range of 165 to 285 nm, and 16 pm for higher wavelengths. Operating parameters of the ICP-OES system were as follows: 1.2 kW RF power, 13 L/min plasma flow rate, 0.8 L/min auxiliary gas

flow rate, 0.8 L/min nebulizer flow rate, 13 L/min coolant flow, 30 rpm sample pump speed, and three replicates ($n = 3$). Calibration solutions of the linear range of $0.01\text{--}0.1 \text{ mg L}^{-1}$ were prepared by diluting the certified standard ICP TraceCert mix solutions (10 mg L^{-1}) 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.

3. Results and discussion

The concentration values and some descriptive statistical data of major minerals analyzed in bottled fruit-flavored mineral water samples are given in Table 2. Frequency distributions of the concentrations of major minerals in bottled fruit-flavored mineral water samples are given in Fig. 1. The comparison of the average concentration of these major cations analyzed in the studied bottled fruit-flavored mineral water samples with those analyzed in bottled drinking and mineral water samples consumed in various countries is presented in Table 3. It can be seen from Table 2 that the order of major minerals analyzed in the studied BFMW samples is $\text{Na} > \text{Ca} > \text{K} > \text{Mg}$ according to their average concentration values.

The concentration of Ca varied from 36 to 380 mg/L with an average of 135 mg/L. The highest Ca concentration was analyzed in the B4 (BFMW16) coded brand, the lowest Ca concentration was analyzed in the B1 (BFMW5) coded brand. As can be seen from Fig. 1, the frequency distribution of the concentration of Ca exhibits a log-normal distribution. 38%, 24%, and 38% of the concentrations of Ca in the BFMW samples are in the range of 36-100, 100-150, and 150-400 mg/L, respectively. Eleven samples belonging to eight brands can be classified as natural mineral water with calcium. The average Ca content is higher than those analyzed in bottled drinking water (BDW) and bottled mineral water (BMW) samples consumed in all countries given in Table 3.

The concentration of K varied from 28 to 189 mg/L with an average of 98 mg/L. The highest K concentration was analyzed in the B5 (BFMW17) coded brand, the lowest K concentration was analyzed in the B9 (BFMW28) coded brand. The frequency distribution of the concentration of K exhibits a near-normal distribution. 58%, 24% and 14% of the concentrations of K in the BFMW samples are in the range of 50-100, 100-150 and 150-200 mg/L, respectively. The average K content is higher than those analyzed in bottled drinking water (BDW) and bottled mineral water (BMW) samples consumed in all countries given in Table 3.

The concentration of Mg varied from 17 to 104 mg/L with an average of 43 mg/L. The highest Mg concentration was analyzed in the B6 (BFMW19) coded brand, the lowest Mg concentration was

analyzed in the B2 (BFMW10) coded brand. The frequency distribution of the concentration of Mg exhibits a log-normal distribution. While 69% of concentrations of Mg in the BFMW samples are in the range of 15-50 mg/L, 31% of them are greater than 50 mg/L. Nine samples belonging to three brands can be classified as natural mineral water with magnesium. The average Mg content is higher than those analyzed in bottled drinking water (BDW) and bottled mineral water (BMW) samples consumed in all countries, except for Slovenia, given in Table 3.

The concentration of Na varied from 11 to 282 mg/L with an average of 139 mg/L. The highest Na concentration was analyzed in the B1 (BFMW7)

coded brand, the lowest Na concentration was analyzed in the B4 (BFMW16) coded brand. The frequency distribution of the concentration of Na exhibits a non-normal distribution. While 24% of concentrations of Na in the BFMW samples are lower than 50 mg/L, 24% of them are greater than 200 mg/L. Seven samples belonging to two brands can be classified as natural mineral water with sodium. Seven samples belonging to five brands can be classified as suitable mineral water sodium diet. The average Na content is higher than those analyzed in bottled drinking water (BDW) and bottled mineral water (BMW) samples consumed in all countries, except for Estonia and Slovenia, given in Table 3.

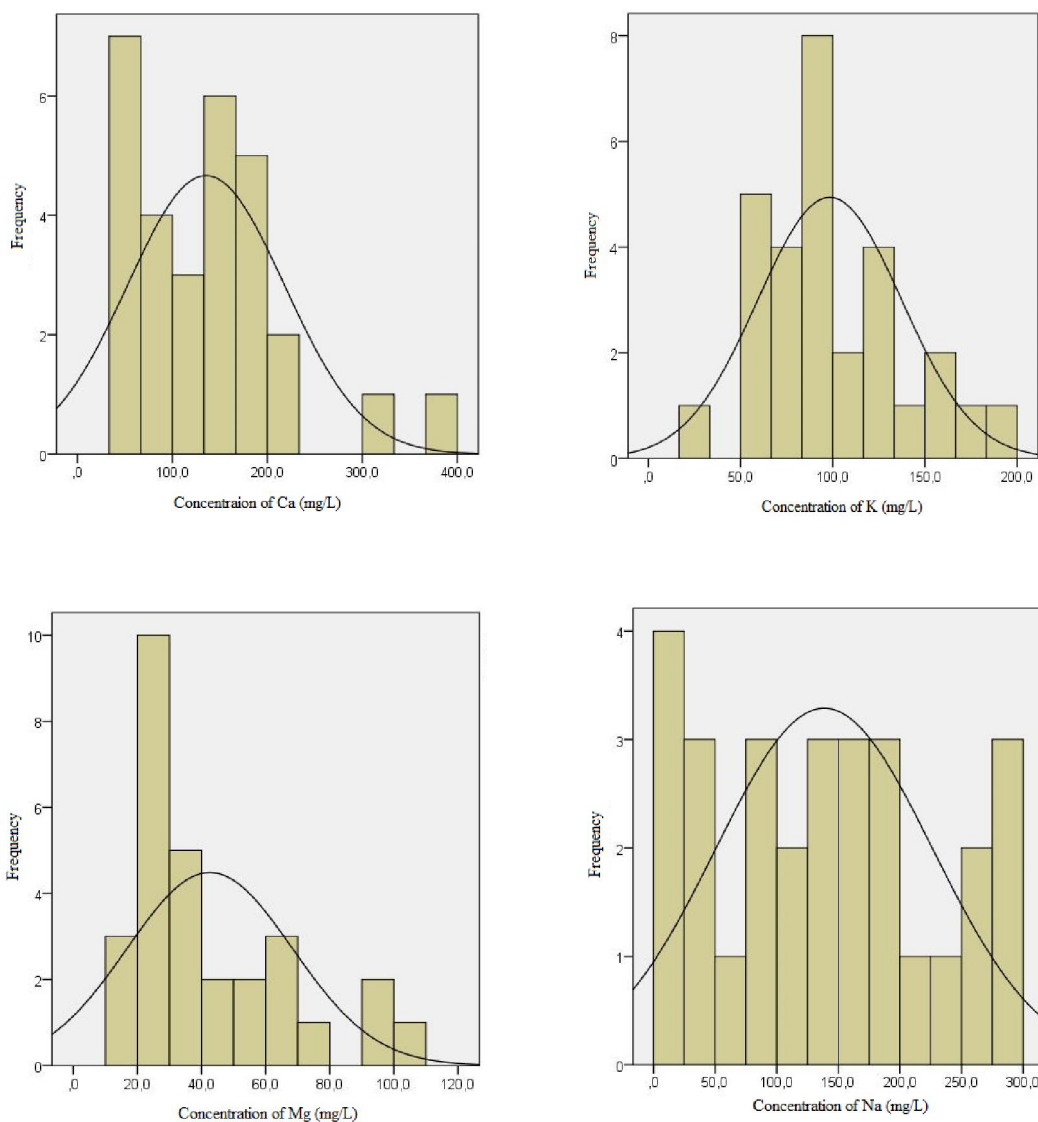


Fig. 1. Frequency distributions of the major minerals in bottled fruit-flavored mineral water samples

Table 1. Information on the bottled fruit-flavored mineral water samples

Brand code	Samples code	Fruit flavored
B1	BFMW1	Mango and pineapple
	BFMW2	Lemon
	BFMW3	Lemon and tangerine
	BFMW4	Kiwi
	BFMW5	Apple
	BFMW6	Watermelon and strawberry
	BFMW7	Black mulberry
B2	BFMW8	Pomegranate
	BFMW9	Lemon
	BFMW10	lemon C plus
	BFMW11	Lemon
	BFMW12	Lemon extra
	BFMW13	Apple
B3	BFMW14	Apple
	BFMW15	Lemon
B4	BFMW16	Watermelon and strawberry
B5	BFMW17	Lemon and tangerine
B6	BFMW18	Strawberry
	BFMW19	Lemon
	BFMW20	Sour cherry
B7	BFMW21	Tangerine
	BFMW22	Lemon
B8	BFMW23	Lemon
	BFMW24	Watermelon and strawberry
	BFMW25	Apple
	BFMW26	Lemon, kiwi and orange
	BFMW27	Pear, mandarin, lime and melon
B9	BFMW28	Lemon
B10	BFMW29	Lemon

Table 2. Concentrations of major minerals analyzed in bottled fruit-flavored mineral water samples

Sample Code	Concentration (mg/L)			
	Ca	K	Mg	Na
BFMW1	43.8	68.6	24.3	276.0
BFMW2	43.4	65.5	23.1	271.2
BFMW3	39.3	65.1	20.0	218.2
BFMW4	55.4	129.4	24.2	229.5
BFMW5	36.4	63.5	18.0	188.6
BFMW6	45.3	157.2	23.8	279.0
BFMW7	48.6	63.6	26.4	281.6
BFMW8	141.3	143.1	21.7	147.5
BFMW9	95.0	181.7	31.4	93.8
BFMW10	136.4	93.1	17.4	189.7
BFMW11	68.0	68.6	24.4	43.2
BFMW12	181.9	118.2	20.1	19.5
BFMW13	76.5	73.3	27.6	65.3
BFMW14	203.1	86.0	43.5	26.9
BFMW15	208.3	84.7	45.8	12.5
BFMW16	380.1	118.2	30.4	11.4
BFMW17	84.9	189.0	30.5	151.0
BFMW18	167.0	83.5	94.6	90.8
BFMW19	197.9	89.1	104.4	156.7
BFMW20	170.7	84.2	76.7	191.0
BFMW21	160.6	116.8	96.1	115.5
BFMW22	117.0	78.5	38.9	124.8
BFMW23	124.3	84.2	56.4	98.4
BFMW24	144.1	90.0	66.3	129.0
BFMW25	154.7	100.8	67.2	250.7
BFMW26	147.4	116.1	66.9	166.2
BFMW27	130.8	160.6	58.5	127.2
BFMW28	189.8	27.9	34.3	22.9
BFMW29	330.9	51.0	21.7	38.3
Average	135.3	98.3	42.6	138.5
Standard error	15.3	7.2	4.8	16.3
Standard deviation	82.6	39.0	25.8	87.9
Median	136.4	86.0	30.5	129.0
Kurtosis	2.0	0.2	0.2	-1.1
Skewness	1.2	0.8	1.1	0.1
Min	36.4	27.9	17.4	11.4
Max	380.1	189.0	104.4	281.6

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

Water type	N	Country	Concentration (mg/L)				Reference
			Ca	K	Mg	Na	
BDW*	10	Chile	36	1	8	25	[27]
BDW	908	Germany	91	3	22	20	[8]
BDW	10	Croatia	57	0.4	17	3	[10]
BDW	13	Spain	42	2	14	45	[28]
BDW	20	Iran	33	1	12	17	[29]
BDW	17	Oman	13	2	10	12	[30]
BDW	17	India	17	3	8	23	[31]
BMW**	186	Italy	69	4	13	20	[32]
BMW	9	Malaysia	41	2	10	11	[33]
BMW	14	Egypt	20	7	8	31	[34]
BMW	9	Serbia	46	2	22	33	[35]
BMW	86	British Isles	46	2	8	18	[11]
BMW	47	Poland	82	6	26	44	[36]
BMW	5	Estonia	69	13	23	212	[4]
BMW	21	Romania	107	6	27	47	[37]
BMW	571	EU	67	2	16	15	[12]
BMW	9	Ethiopia	13	5	6	38	[13]
BMW	22	Nordic	6	1	11	12	[9]
BMW	53	Iran	50	1	12	8	[29]
BMW	35	Slovenia	120	15	104	218	[38]
BFMW	29	Turkey	135	98	43	139	This study

*BDW: Bottled drinking water, **BMW: Bottled mineral water

4. Conclusion

Since natural mineral waters are mostly supplied from areas near geothermal regions with deep groundwater circulation patterns and recent tectonic/volcanic activity differences in major mineral concentrations were observed in the bottled natural fruit-flavored mineral water samples obtained from different parts of Turkey. A comparison of the average values of the major minerals in the studied bottled natural fruit-flavored mineral waters revealed that the concentrations of Ca, K, Mg, and Na are higher than those consumed in many countries. The BFMW samples belonging to the B2 brand are calcium, magnesium, and sodium waters. The BFMW samples belonging to the B6 and B7 brands are both calcium and magnesium waters. The BFMW samples belonging to the B2, B3, B4, B9, and B10

brands are water with calcium and suitable for a sodium diet. The BFMW samples belonging to the B1 brand are sodium water.

Acknowledgments

The author sincerely thanks Merve Zurnacı for helping with major mineral analysis.

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8/12/2021