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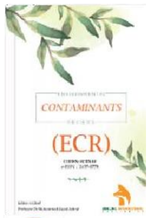

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RESEARCH ARTICLE

EFFECT OF HEATING AND FREEZING ON SOME BOTTLED WATER QUALITY IN HAWLER CITY, KURDISTAN REGION, IRAQ

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ABSTRACT

The purpose of this study was to evaluate the impact of freezing and heating storage on the physicochemical properties (EC, pH, Alkalinity, Hardness, TDS, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, and NO_{3-2}) that make four different types of bottled water (Al-Hayat, Zalal, Sky water, and Masafy) suitable for drinking. The physicochemical parameters of the bottled water measured in this study were compared to the manufacturer's labeling found on the bottles as well as to the WHO and IBWA standard guideline values. The results indicate, the physicochemical properties of all bottled water samples are within the international guidelines of bottled water and not the same that reported on the bottle label. The results show each of heating exposure and freezing of storing cause changes in all physicochemical properties of water in the plastic bottle.

KEYWORDS

Water, storage, condition, heating, freezing bottled water.

1. INTRODUCTION

Water is the single most abundant substance in the human body, making up to 60% of an adult's weight and up to 80% of an infant's weight (Abd El-Salam et al., 2008). Bottled water is the fastest growing drink choice over world, Some people drink bottled water as an alternative to other beverages; others drink it because they prefer its taste or think it is safer than their tap water (Oyelude and Ahenkorah, 2012; Taiwa et al., 2010). Demand for water increases day after day based on the facts of climate change, rapid population increase and industrialization (Atasoy et al., 2011). Water is the key to life: a crucial resource for humanity and the rest of the living world. Humans can go without food for a few days, but not without water for a few days. Taste, fashion, and convenience are just a few of the reasons why people purchase bottled water. Water quality, including natural mineral content and treatment methods, affect how the water tastes. That being said, safety isn't always determined by taste.

The purchased bottle's bacteriological quality is significantly impacted by refrigeration (Abd El-Salam et al., 2008). In many European countries, bottled water is gradually taking the place of tap water as the primary source of drinking water. It is marketed in inexpensive plastic or glass bottles, which are frequently kept in these bottles for several months prior to consumption under erratic circumstances (Oyelude and Ahenkorah, 2012). Reusable water bottles are becoming more and more common as people become more conscious of the effects that transportation and water bottling have on the environment. Aluminum is a well-known brand in this category, but it also has a unique, non-toxic liner. Stainless steel is the material of choice for a second kind of widely used bottle. As far as we are aware, no research has been published on trace metal contamination resulting from leaching from such containers (Taiwo et al., 2010). Over the world, drinking bottled water has grown in popularity. The use of bottled waters has increased due to population growth and lack of access to clean drinking water. In some areas, consumers are particularly concerned about environmental pollutants and their negative effects on the local water supply, as well as a number of local municipality water irregularities, such as the water's off-odor and taste and high fluoride and chloride levels. However, those who have weakened immune systems need more safe drinking water (Oyelude and Ahenkorah, 2012).

Standard techniques were used to analyze the physicochemical properties (EC, pH, Alkalinity, Hardness, TDS, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, and NO_{3-2}) of four different brands of bottled water found in the Kurdistan region of Iraq. The World Health Organization's (WHO) and International Bottled Water Association's (IBWA) guidelines for guideline values were compared with the manufacturer's labeling found on the bottles and the physicochemical properties of the bottled water measured in this study. The investigation of the physicochemical properties change when bottled water is stored in the oven and refrigerator at varying temperatures over a period of time. The quality of the bottled water samples, according to the results, was within the allowable limit, despite exposure to temperature and freezing changes over time. The investigation of the physicochemical characteristics change when bottled water is exposed to intense freezing and is stored at varying temperatures. WHO and IBWA state that all bottled waters were of a quality appropriate for drinking for every variable under investigation.

2. THE AREA'S DESCRIPTION

In Hawler City, the study was conducted. The studied region, Hawler City, spans approximately 70 km^3 between latitudes 36º 09ˉ and 36º 14' N and longitudes 43º 58 and 44º 03ˉ E (Toma et al., 2013). Before and after being exposed to severe freezing and being stored at varying temperatures in January through March, the four distinct bottled waters were gathered from different stores in Hawler City. Four different popular brands of bottled water that are brought to Hawler City and consumed by a diverse range of people were used in the current investigation. Many sources are used to create these bottled waters (Hawler, Kirkuk). Each table (1 and 2) shows the type of water as well as its source.

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Table 1: The bottled water type and source of each brand		
Bottled water brands	Water type	Source of water
Al-HAYAT	Natural spring water	Iraq - Kirkuk
Zalal	Natural spring water	Iraq - Erbil
Sky water	Natural mineral water	Iraq- Erbil
Masafi	Pure mineral water	Iraq- Erbil

Table 2: Physicochemical variables in bottled water during studied period								
Site number	Al-HAYAT		Zalal		Skay water		Masafy	
Parameters	M	L	M	L	M	L	M	L
pH	7.8	7.4	7.6	7.36	7.1	73	7.2	7.5
Ec	82	NI	54	NI	132	NI	154	NI
TDS	52.48	NI	34.56	NI	84.48	84	98.56	120
Alkalinity	123	NI	149.2	NI	100.2	NI	128.6	NI
hardness	128.1	NI	129.8	NI	98	NI	100.9	NI
Ca+2	28.3	22	27.6	29	26.74	12	20.3	24
Mg+2	13.8	10	14.6	3.4	18.6	7	12.5	7
Na+	11.7	N	3.0	2.90	6.7	5	3.09	21.9
K+	1.5	0.3	0.3	NI	1.17	0.2	0.4	1.06
NO3	5.5	NI	8.5	1.1	6.8	7	5.63	6.3

M: measured L: labeled NI: not included

3. Materials

Four different brands of bottled water (Al-Hayat, Zalal, Sky water, and Masafy) were gathered from various supermarkets in the Kurdistan region of Iraq, specifically Hawler city, between January and March. Tables 1 and 2 list each brand name and origin. EC, TDS, pH, Alkalinity, Total Hardness, Ca^{+2}, Mg^{+2}, Na^{+2}, K^{+}, and No_{3-2} were examined using the (WHO) guidelines for drinking water quality table (3) and the (APHA) Standard Methods for the examination of water and waste water (APHA, 1989; WHO, 1984; Miyazaki et al., 2008).

Table 3: International standard related bottled water quality			
Parameters	Unite	WHO (2006) drinking water	IBWA () Bottled water
pH	_	6.5 - 9.5	6.5_8.5
EC	µs/cm	1000	1000
TDS	mg L-1	500	500
Alkalinity	MgCaCO3/L	200	200
Hardness	mgCaCO3/L	200	200
Ca+2	mg L-1	100	100
Mg+2	mg L-1	30	30
Na+	mg L-1	20	20
K+	mg L-1	10	10
NO3	mg L-1	50	44

4. Result and Discussion

Bottled water constitutes an alternative source for meeting daily potable water needs. Production of bottled water has shown a rapid progress in Kurdistan also just like in all over the world (Kazmi and Khan, 2005; Addiscot and Benjamin, 2004). Effects of heating and freezing on the physicochemical characteristics of four bottles of water that were collected in Erbil City from various stores between January and March As indicated in tables 4 to 15, compare the results of these properties to the Bottled Water Association (IBWA) and World Health Organization (WHO) standards, as indicated in table 3. Temperature affects pH electrodes in a number of ways, both chemically and physically. First of all the study area's samples had pH values that varied from (7.0 to 8); the pH values revealed a notable discrepancy between the measured and labeled PH values. The IBWA specifies that the limited PH value for drink water is between 6.5 and 8.5, and the water's PH indicates a slightly alkaline trend. In general, the catchment area's geology and buffering capacity have an impact on the pH of the water.

Table 4: Effect of temperature o n AL-Hayat bottled water after 7 days										
Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.8	82	52.48	123	128.1	28.3	13.8	11.7	1.5	5.5
25°C	8.6	402	257.7	163	155	39	57	5.5	1.6	8.5
35°C	8.2	387	247.7	121	162	41	60	6.1	1.7	7.5

Table 5: Effect of temperature on Zalal bottled water after 7 days										
Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
Control	7.6	54	34.54	149.2	129.8	27.6	14.6	3.0	0.3	8.5
25°C	7.9	300	192	112	122	31	44	7.4	2.1	2
35°C	8.3	302	193	101	132	33	50	2.2	0.3	2.5

Table 6: Effect of temperature on Sky water after 7 days										
Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.1	132	84.48	100.2	98	26.74	18.6	6.7	1.17	6.8
25°C	8.1	304	194.6	100	91	23	33	12.3	0.7	11
35°C	8.4	304	194.6	100	93	24	33	12.5	0.7	10.5

Table 7: Effect of temperature on masafy bottled water after 7 days										
Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.2	154	98.56	128.6	100.9	20.3	12.5	3.09	0.4	5.63
25°C	8.5	169	125	90	110	28	40	3.2	0.5	13.5
35°C	8	300	192	130	76	19	28	7.6	2.2	12.5

Table 8: Effect of temperature on HAYAT bottled water after 14 days

Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.8	82	52.48	123	128.1	28.3	13.8	11.7	1.5	5.5
25°C	8.3	295	189	112	115	29	43	17.9	0.9	6.5
35°C	6.7	260	166	115	99	25	37	2.4	0.5	2.5
45°C	7.5	295	188	125	93	23	35	3.8	0.6	1.5

Table 9: Effect of temperature on zalal bottled water after 14 days

Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.6	54	34.56	149.2	129.8	27.6	14.6	3.0	0.3	8.5
25°C	7.4	300	192	135	128	32	70	2.3	0.4	2
35°C	7.2	300	192	139	136	34	52	2.3	0.4	3.5
45°C	7.4	238	152	125	119	30	45	2.3	0.4	2.5

Table 10: Effect of temperature on sky water bottled water after 14 days

Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.1	132	84.48	100.2	98	26.74	18.6	6.7	1.17	6.8
25°C	7.9	300	192	98	91	23	33	2.3	0.5	105
35°C	8	350	224	133	95	24	35	2.3	0.5	125
45°C	7.5	286	183	115	91	23	33	15.4	0.8	9.5

Table 11: Effect of temperature on masafy bottled water after 14 days

Exposed to temperature	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.2	154	98.56	128.	100.9	20.3	12.5	3.09	0.4	5.63
25°C	7.6	314	201	128	139	35	51	4.2	0.6	14.5
35°C	7.4	250	160	100	70	18	26	3.5	0.6	12
45°C	7.5	250	160	99	76	19	28	3.6	0.6	13

Table 12: Effect of freezing on Hyayat bottled water

Exposed to freezing	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.8	82	52.48	123	128.1	28.3	13.8	11.7	1.5	5.5
7 days	8.3	330	211	113	112	28	42	18.1	0.9	6.5
14 days	8.3	295	189	112	115	29	43	17.9	0.9	6.5

Table 13: Effect of freezing on zalal bottled water

Exposed to freezing	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.6	54	34.56	149.2	129.8	27.6	14.6	3.0	0.3	8.5
7 days	7.4	350	224	115	127	32	47	2.3	0.4	2.5
14 days	7.5	325	208	105	120	30	46	2.3	0.4	3

Table 14: Effect of freezing on sky water

Exposed to freezing	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.1	132	84.48	100.2	98	26.74	18.6	6.7	1.17	6.8
7 days	7.6	325	208	125	112	28	32	15.2	0.8	10
14 days	7.9	300	192	98	91	23	33	2.3	0.5	10.5

Table 15: Effect of freezing on masafy bottled water

Exposed to freezing	pH	EC	TDS	Alkalinity	Hardness	Ca+2	Mg+2	Na+	K+	NO3
control	7.2	154	98.56	128	100.9	20.3	12.5	3.09	0.4	5.63
7 days	7.3	300	192	110	89	23	31	3.5	0.6	12.5
14 days	7.7	350	224	101	63	16	23	3.5	0.6	12.5

Due to the effects of temperature, accurate measurement and reporting of pH data has long been a challenge. Any solution's viscosity will decrease and its ions' mobility in the solution will increase as its temperature rises. Because of the dissociation of molecules, a rise in temperature can also cause an increase in the number of ions in solution (this is particularly true for weak acids and bases). Since pH is a measurement of the concentration of hydrogen ions, a change in temperature in a solution will cause a corresponding change in water's pH (Oyelude and Ahenkorah, 2012).

Electrical conductivity (EC) is a measure of the ability of water to conduct an electric current and depends on concentration of the ions (higher concentration, higher EC). Temperature of the solution (high temperature, higher EC). Specific nature of the ions (higher specific ability and higher valence, higher EC) Conductivity changes with storage time and temperature.

Due to its ability to provide a reliable estimate of the amount of dissolved material in the water, conductivity is the most important metric for measuring water quality (Taiwa et al., 2010; Atasoy et al., 2011). The variation in EC values between the bottled water samples could be attributed to variations in the water's composition from different sources. This indicates that there is a close relationship between EC and TDS (Theroux et al., 2001). The diversity of soil composition includes different mineral rocks. Additionally, an increase in water conductivity is accompanied by an increase in total dissolved solids.

Water's capacity to neutralize acids is measured chemically as alkalinity. Alkalinity can also be defined as the capacity of water to withstand pH shifts caused by the addition of acids or bases. The main cause of alkalinity in natural waters is the presence of weak acid salts, though in harsh environments, strong bases, such as OH-, may also be involved. Bicarbonates, which are primarily found in natural waters, are a result of the weathering of carbonate minerals in rocks and soil as well as the partitioning of CO2 from the atmosphere.

Other salts of weak acids, such as borate, silicates, ammonia, phosphates, and organic bases from natural organic matter, may be present in small amounts. Alkalinity, by convention, is reported as mg/L CaCO3 since most alkalinity is derived from the weathering of carbonate minerals (Abdouleish, 2012).

The average alkalinity level in bottled water was between 20 and 455 mg CaCO3/l. The type and quantity of rocks, such as sedimentary rock, particularly calcareous rock, which is rich in carbonate, has a high base saturation, is well buttered, and generally gives rise to circumvented (pH = 7) or slightly alkaline hard water (PH of 7.5–8.5), may be related to this variation in alkalinity (Zatar et al., 1999).

Originally, the ability of water to precipitate soap was the definition of hardness. Calcium and magnesium precipitate soap, forming a curd that feels unpleasant on the skin (red, itchy, or dry skin), tends to waste soap, and results in "bathtub ring" and dingy laundry (yellowing, graying, loss of brightness, and reduced life of washable fabrics). Synthetic detergents have been developed to address these issues. Sequestering agents, which are added to these detergents, "tie-up" the hardness ions to prevent them from forming problematic precipitates (Addiscott and Benjamin, 2004). The total hardness in percent of the study fluctuated between a record 20 mg CaCO3/l in Pearl water and a maximum of 300 mg CaCO3/l in Kani water. This means that the hardness in bottled water ranged from soft to moderately hard; the reasons for this could be attributed to the source, the geographical and soil properties of the catchments area, a variety of human activities, and the climate condition, which can affect the hardness value in any water source (Environment Protection Agency Ground Water and Drinking Water, 2006; Gupta et al., 2001).

Magnesium and calcium are relatively common elements. Magnesium comes in at number eight and calcium is the fifth most abundant element in nature. Every natural water contains both of these components. The erosion of minerals like calcite and magnesite as well as rocks like limestone and dolomite is the most frequent source of calcium and magnesium in groundwater. Drinking water containing magnesium may taste different and act as a laxative. The two main minerals that contribute to hard water are calcium and magnesium. Magnesium and calcium can have a detrimental effect on the quality of drinking water because they increase hardness. These effects are primarily decorative. For more details, see our hard water fact sheet (WHO, 2011).

Sodium salts are typically very soluble in water and seep into surface and groundwater from the terrestrial environment. Since they are nonvolatile, particulate matter is the only way that they can be found in the atmosphere. The temperature of the solution and the related anion affect the sodium in water taste threshold. Approximately 20 mg/liter for sodium carbonate, 150 mg/liter for sodium chloride, 190 mg/liter for sodium nitrate, 220 mg/liter for sodium sulfate, and 420 mg/liter for sodium bicarbonate are the threshold values at room temperature. It is improbable that sodium by itself causes cancer. But eating a lot of salt can make chemicals more potent in their ability to cause cancer such as N-methyl-N'-nitro-N-nitrosoguanidine in drinkingwater by causing irritation of the gastroduodenal tract, thus increasing the exposure of epithelial cells to the carcinogen and resulting in an increased incidence of gastric tumour (Toma et al., 2013).

Sodium is a crucial element in bottled water and the primary cation in the hydrosphere. High levels of sodium can lead to health issues, while low levels should be consumed in moderation. The concentration of sodium ions in water ranges from 0.1 to 59.5 mg/l. Methemoglobinemia, also known as blue baby syndrome, is a condition commonly found in infants under six months of age that can be brought on by high nitrate levels in water. In comparison to older children and adults, an infant's stomach acid is weaker. Without analyzing your water chemically, you cannot identify nitrate, a tasteless, colorless, and odorless substance. Get a certified laboratory to test the water in your private well on an annual basis. The local health department or Colorado State University Extension county offices usually can supply the name of an approved testing laboratory in your area.

Sample water for nitrate testing at the well site or at a tap inside the house. Place samples in clean, 4- to 16-ounce plastic containers. Send the sample to a laboratory immediately. Refrigerating it will help keep it intact until it reaches a laboratory. Do not freeze it. (APHA, 1989). The inorganic salts and trace amounts of organic matter that are dissolved in water are referred to as total dissolved solids, or TDS. Carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions, as well as calcium, magnesium, sodium, and potassium cations, are typically the main components. Water's flavor may be impacted by dissolved solids. Panels of tasters have assigned the following ratings to drinking water's palatability based on its TDS content: excellent, less than 300 mg/litre; good, between 300 and 600 mg/litre; fair, between 600 and 900 mg/litre; poor, between 900 and 1200 mg/litre; and unacceptable, more than 1200 mg/litre.

The flat, bland flavor of water with incredibly low TDS concentrations may also make it unsuitable. The sources of TDS in water supplies are sewage, industrial wastewater, urban and agricultural runoff, and natural sources. The TDS loading of water supplies can also be influenced by salts used for deicing roads. It has been discovered that TDS concentrations in natural sources can range from less than 30 mg/litre to up to 6000 mg/litre, contingent on the solubilities of the minerals in various geological regions. Thus, in 36 of the 41 Canadian rivers that were surveyed, the values, expressed as the sum of the constituents, were below 500 mg/litre, whereas in a survey of the Great Lakes, the levels varied from 65 to 227 mg/litre.

(In the past 70 years, TDS levels in all of the Great Lakes—aside from Lake Superior—have increased, with Lakes Erie and Ontario seeing increases of 50–60 mg/litre (Zatar et al., 1999; Addiscott and Benjamin, 2004; Environmental Protection Agency Ground Water and Drinking Water, 2006; Gupta et al., 2001). In Australia's Kent River, there was a threefold rise in TDS between 1960 and 1980. Road de-icing caused a tenfold increase in salinity in Burlington, Massachusetts, groundwater between 1955 and 1970. After that, using de-icing agents was forbidden (WHO, 1984).

Potassium is a necessary element for human health and is rarely, if ever, present in drinking water at amounts that should worry healthy people. It is present in many parts of the environment, such as all natural waters. Because potassium permanganate is used as an oxidant in water treatment, it can also happen in drinking water. In certain nations, potassium chloride is combined with or used instead of sodium chloride in ion exchange systems to soften household water (Ma, 2005; Hammer, 1986; Bartram and Balance, 1996; Rump, 1999). This allows potassium ions to exchange with calcium and magnesium ions. It has been suggested that potassium salts could replace some or all of the sodium salts used in the desalination process. Given the cost differential, the latter appears to be an unlikely development at this time. It is possible to treat drinking water with potassium permanganate.

As a result, the amounts of potassium in drinking water are comparatively lower than those that arise from the use of potassium chloride-based water softeners. The maximum concentration of added potassium when using potassium permanganate to treat water is 10 mg/l; however, concentrations would typically be lower (Miyazaki et al., 2008). The potassium ion concentration in the current study varied from 0 to 1.9 mg/l. The sodium concentration in bottled water was more abundant than the potassium concentration, The reason for this is that potassium seeps into the structure of some clay minerals during the weathering processes, and many potassium minerals have a higher resistance to weathering than sodium minerals, which have a lower resistance to weathering. As a result, sodium values are greater than potassium values (WHO, 1985b; Arbuckle et al., 1988; Toma, 2009; Madison and Brunett, 1985; WHO, 2004). The study found that there was a variation in the concentration of sodium and potassium in different bottled water. This variation could be attributed to various factors such as the drainage basin's geology and soil formation, atmospheric deposition, human activity, and the chemical composition of ground water and atmospheric deposition of solute through wet and dry precipitation (Kazmi and Khan, 2005).

5. Conclusion

Using accepted techniques, the physicochemical characteristics (EC, pH, Alkalinity, Hardness, TDS, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, and NO_{3-2}) of four different brands of bottled water from the Kurdistan region of Iraq were examined. The World Health Organization (WHO) and International Bottled Water Association (IBWA) guidelines for guideline values were compared with the physicochemical properties of the bottled water measured in this work, as well as the manufacturer's labeling found on the bottles. The investigation of the physicochemical properties change when bottled water is stored in the oven and refrigerator at varying temperatures over a period of time. The quality of the bottled water samples, according to the results, was within the allowable limit, despite exposure to temperature and freezing changes over time. The findings show that, contrary to what is stated on the bottle label, the physicochemical characteristics of every sample of bottled water fall within international guidelines. The findings demonstrate that all of the physicochemical characteristics of the water in the plastic bottle are altered by heating exposure and freezing during storage.

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