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Classification of bottled waters marketed and consumed in Algeria through statistical approaches

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ABSTRACT

The main objective of this work consists of classifying 30 brands of water bottled and marketed in Algeria, based on their physicochemical compositions and their comparison with some foreign brands recognized in their countries or on a world scale. Relevant to this, descriptive statistics, as well as hierarchical ascendant classification (HAC) and principal component analysis (PCA), were used to analyse the data. The results of this study highlighted a similarity between some Algerian brands and other foreign brands of water in terms of mineral content. Moreover, the results obtained by using PCA and HAC allowed us to divide the sample of Algerian mineral waters into three distinct groups, each with similar physicochemical characteristics. The first group (Soummam, Manbaa Al Ghezlane, Mouzaia, Amane, Djmila, and Hayet) is characterized by very high levels of mineral salts compared to the other brands. The second group (Guedila, Tazliza, Arwa, Baniane, Saida, Ifri, Messerghine, Sfid, Mansourah, Batna, Mileza, S. Rached, Dhaya, Qniaa, and Lejdar) is distinguished from the first group by its average mineralization. Finally, the third group (Fezguia, Nestlé, Ovitale, L. Khedidja, A. Bouglez, Ayris, Righia, Togi, and Toudja) presents a very low mineralization.

Key words: Algeria, HAC, mineral water, PCA, physicochemical composition

HIGHLIGHTS

- Use of statistical approaches for the classification of 30 brands of water bottled and marketed in Algeria.
- Comparison of these mineral waters with other regional and European water brands.

INTRODUCTION

On a global scale, bottled mineral water currently represents the most important and dynamic market of the beverage and food industry (Mouhoumed *et al.* 2020; Sekiou & Tamrabet 2022). This is because consumers perceive bottled water to have better organoleptic and physicochemical properties and to be even healthier than tap water (Tapias *et al.* 2022). The development of the bottled water industry increased considerably in the last decades, even in countries where tap water quality is considered excellent.

Algeria, following the example of the Maghreb countries, has also experienced a tremendous growth and development in mineral and spring water industry in recent years. This growth has been materialized by the establishment of about ten mineral and spring water exploitation and production units throughout the national territory (Hazzab 2011).

The opening up of the market, imposed by the economic reforms and the evolution of the consumption habits of Algerians, has led to both a diversification of the offer and an exceptional increase in consumption. Currently, almost all social categories and at all ages consume mineral water. According to the Association of Algerian Drink Manufacturers (APAB), the annual consumption of mineral water in Algeria is 2.7 billion litres, i.e. 60 litres per inhabitant per year; a figure that will undoubtedly increase in the future (Ait 2021).

Numerous studies have addressed the composition of bottled mineral water out across the world and in Algeria at different levels (local, national, or continental) and have evaluated their chemical quality and their origin according to the geology of

the water reservoir (Astel *et al.* 2014; Sekiou & Kellil 2014; Mouhoumed *et al.* 2020; Iyakare *et al.* 2021; Turhan 2021; Moreno *et al.* 2022; Sekiou & Tamrabet 2022).

Although some authors, such as Tapias *et al.* (2022) and Russel *et al.* (2019), consider that consumed mineral bottled water can be a relevant source of essential minerals in the daily diet (Ca^{2+}, Mg^{2+}, and Na^{+}), in their conclusions, they do not present a preference for one type of water or another, leaving the answer to the criterion of healthcare specialists.

Given that different categories of people such as sportsmen and women, pregnant, or breastfeeding women, the elderly and people on a diet obviously do not have the same mineral requirements (Constant & Hawili 2011; Sghaier & Ben Abdallah 2018; Maton 2019). So, the choice of the brand of water to drink can be variable and it depends on the personal necessity, and in view of the great diversity of brands of water marketed in Algeria, consumers and health specialists are sometimes confused as to which brand of water is suitable for them, because some brands are more mineralized than others.

The main purpose of this study is to make a classification of the most commercialized mineral waters in Algeria, as well as to compare their mineralization with some regional and European brands recognized in their regions or worldwide and whose physicochemical compositions available in the literature. Through this classification of the Algerian brands of mineral water and comparisons with other world brands, we help consumers and health specialists to choose the suitable brand of mineral water.

DATA AND METHODS

Collection of water samples

The physicochemical parameters of the brands of bottled water marketed in Algeria, Tunisia, Morocco, France, and Switzerland selected in this study were taken directly from the labels affixed to the water bottles. Table 1 shows the main characteristics for each brand of Algerian water (company, source, origin, and temperature of the water). Table 2 groups together the main physicochemical parameters, i.e. the pH and the concentrations of dissolved anions and cations, for all brands of water, whether Algerian or foreign.

Statistical approaches used

The statistical analysis methods such as hierarchical ascendant classification (HAC) and principal component analysis (PCA) were chosen according to the objectives of the study for the classification and characterization of the 30 Algerian water brands. These methods were applied by using XLSTAT software.

Internationally, many studies have applied HAC and PCA for the classification of surface or groundwater (Astel *et al.* 2014; Cvejanov & Škrbić 2017; Mouhoumed *et al.* 2020). Similarly in Algeria, several authors have used these techniques to classify water samples into distinct hydrochemical groups (Mézédjri 2008; Belkhiri *et al.* 2011; Brins & Boudoukha 2011). This technique has been adopted in many hydrogeochemical studies (Maqsoud 1996 in Maqsoud *et al.* 2004; Sekiou & Tamrabet 2022). Its efficiency is superior to other methods such as Collins bar, Stiff's pie chart, Schoeller's, and Piper's diagrams (Maqsoud *et al.* 2004).

Hierarchical ascendant classification

HAC is a numerical or automatic classification method of chemistry data and the geochemical models formulation (Palm 1996; Ernest Kouassi *et al.* 2010; Bu *et al.* 2020; Sekiou & Tamrabet 2022). It was used to distribute all 30 brands of water studied into water groups as homogeneous as possible in terms of physicochemical characteristics (intra-group homogeneity), whereas the groups are the most dissimilar (intergroup heterogeneity). HAC was applied on a matrix of 30 rows (Algerian water marks) and 7 columns (chemical elements). In this classification, we considered only the mineral salts which are necessary for human health.

Principal component analysis

PCA was used as a complementary analysis to HAC for the characterization of the identified water groups through this latter analysis approach. PCA is an essentially descriptive statistical method and helps a tool to interpret a data matrix. Its objective is to present, in graphic form, the maximum information continued in a data table of n rows and p columns (Philippeau 1992). It allows studying the relationships that exist between quantitative variables, whatever be the a priori structure, nominal, ordinal, numerical of each other (Palm 1998).

Table 1 | Physicochemical characteristics of bottled water in Algeria

Brand	Company	Region	Origin	Temperature (°C)
Fezguia	SARL FEZGUIA	Oum El-bouaghi	Spring water	–
Guedila	SARL GUEDILA	Biskra	Natural mineral water	–
Tazliza	SARL TAZLIZA	Adrar	Spring water	–
Arwa	SARL JUS LABELLE	Sétif	Spring water	–
Nestle Pure Life	NESTLE WATERS SPA ALGERIE	Blida	Spring water	16.7
Ovitale	SARL ITHRI BOISSANS	Béjaïa	Spring water	
Baniane	SARL BANIANE	Biskra	Natural mineral water	–
Lalla Khedidja	CEVITAL UNITE D'EAU MINERALE	Tizi Ouzo	Natural mineral water	–
Ain Bouglez	SARL ESSALSABIL	El Tarf	Spring water	19.4
Soummam	SARL SOUMMAM	Béjaïa	Spring water	
Saïda	EURL EM SAIDA	Saïda	Natural mineral water	12.7
Ifri	SARL IBRAHIM&FILS	Ouzellaguen Béjaïa	Natural mineral water	22.5
Ayris	SARL NOMAD	Akbou Béjaïa	Spring water	19.3
Toudja	SARL SET	Béjaia	Natural mineral water	–
Messerghine	EURL SAPE	Oran	Natural mineral water	13.1
Manbaa Al Ghezlane	SARL TAHRAOUI	Biskra	Natural mineral water	19.5
Mouzaia	AQUA SIM S.P.A	Blida	Natural mineral water	–
Sfid	SARL AEMBG	Saïda	Natural mineral water	–
Mansourah	SARL	Tlemcen	Natural mineral water	
Batna	ESP	Batna	Natural mineral water	19.1
Mileza	EURL	Bordj-bou Arreridje	Spring water	–
Amane	ALKARMA	Béjaïa	Natural mineral water	19.4
Sidi Rached	SAEMO	Tizi Ouzou	Spring water	28
Dhaya	LMBC	Sidi bel Abbes	Spring water	18.4
Hayet	SARL	Alger	Spring water	>25
Qniaa	SARL	Béjaïa	Spring water	–
Togi	SARL EMBG TOGI	Chorfa, Bouira	Spring water	–
Righia	AQUA	El Tarf	Spring water	–
Djemila	SARL eau minérale djemila	Sétif	Natural mineral water	–
Lejdar	SMIGROUP	Tiaret	Spring water	–

RESULTS AND DISCUSSION

Descriptive statistics

The simple descriptive statistics of the various physicochemical elements (major cations and anions) of the Algerian water brands studied are shown in Table 3. An examination of this table reveals a significant variability among the different water brands in terms of mineral salt richness. The most discriminant elements whose coefficient of variation exceeds 50% are: Magnesium (55%), Sodium (74%), Potassium (73%), Chlorides (66%), Sulphates (68%), Nitrates (91%), and Nitrites (171%). The pH, which varies from 6.8 to 7.8, is the least discriminant element with a low coefficient of variation (3%). Therefore, elements of low discriminating power such as pH and fort discriminating nitrites were not considered in the HAC and PCA. These results reveal the mineralogical differences of the different aquifer sites of these mineral waters. It should also be noted that samples with similar chemical characteristics often have similar hydrological histories, similar recharge areas, and similar infiltration and flow paths in terms of climate, mineralogy, and residence time (Cüneyt *et al.* 2002). Figure 1 also shows the strong variation in the physicochemical composition between the different brands due to the large difference

Table 2 | Physicochemical parameters of the retained bottled waters

Chemical characteristics	Ca^{+2} (mg/L)	Mg^{+2} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	HCO_3^- (mg/L)	SO_4^{2} (mg/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	pH
Fezguia	63.20	26.91	14	1	30	262.30	38	19	00	7.06
Guedila	78	37	29	2	40	236.68	95	4.5	<0.01	7.35
Tazliza	48	20	48	8	76	104	96	19.97	0.01	7.32
Arwa	120	23	56	1	100	256	104	46.5	<0.01	7.33
Nestle pure life	55	17	15	0.5	18	210	33	4.6	0	7.8
Ovitale	91	14	30	1	50	214	86	13	00	6.92
Baniane	91	56	34	03	41	280	158	2.6	00	7.5
Lalla khedidja	53	7	5.5	0.54	11	160	7	0.42	00	7.22
Ain bouglez	46	3.75	29	1	30	48.8	10	9	0.06	6.87
Soummam	114	32	71	2	78	293	196	19.20	<0.01	7.21
Saida	68	50	58	02	81	376	65	15	0.00	7.5
Ifri	99	24	15.8	2.1	72	265	68	15	<0.02	7.2
Ayris	65.5	6.8	28.5	1.9	37	234.24	75	2.7	0.01	7.78
Toudja	56.6	15.2	36	0.7	54.6	–	19.6	2.55	0.02	7.19
Messerghine	52	42	45	3	78	260	50	5	00	7.2
Manbaa Al Ghezlane	93	31	68	4	84	326	153	8.9	0.02	7.1
Mouzaia	136	75	145	3	150	671	120	20	<0.02	7.5
Sfid	74	35	28	02	68	268	91	25	0.0	7.12
Mansourah	85	37	30	1	48	362	53	12	00	7.00
Batna	59	45	15	2	2	378.2	40	0.5	00	6.8
Mileza	111	34	29	1	10	311	190	3.2	<0.01	7.33
Amane	105	37	111	5	131	379	150	12.97	0.01	6.98
Sidi rached	134.38	6.69	29.21	2.45	50	235	139	21.8	0	7.39
Dhaya	66.5	40	23.5	2	60.5	263	62	28	<0.01	7.2
Hayet	120	36	100	1	138	–	210	14.6	0	7.3
Qniaa	111.66	26.97	48.22	2.48	92.1	259.02	66.6	12.39	0.01	7.24
Togi	73.41	19.25	36	1.8	43.7	–	28.9	5.39	0.01	7.46
Righia	8	3	12.8	0.35	19.3	24.4	1	2.5	0.02	7.19
Djmila	98	20	100	3	170	281	50	5	0	7.04
Lejdar	64	37	30	4	41	308	66	50	0.1	7.53
Foreign water brands										
Aproz	360	70	6	2.5	20	250	930	1.5	–	–
Evian	78	24	5	1	4.5	357	10	3.8	–	7.2
Vittel	240	42	5.2	1.9	8	8	400	4.4	–	7.6
Cristaline	43	11	44	2.3	76	180	6	1	–	7.5
Sidi Ali	13	9	26	3	14	104	42	0	–	–
Ain Saiss	63.5	35.5	8	1	19.8	372	3.8	7	–	–
Ain Ifrane	67.73	40.61	3	1	10.65	402.6	5.63	5.18	–	–
Garci	169	75	436	8	328	1,119	70	3	–	–
Aqualine	131	35	39	0.6	50	235	249	4.4	–	–
Sabrine	35	17	56.45	2.8	27	244	27.5	17	–	–
Bargou	89	9.9	19.9	0.71	36.7	285.4	13.5	1.7	–	–

(*Continued.*)

Table 2 | Continued

Chemical characteristics	Ca^{+2} (mg/L)	Mg^{+2} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	HCO_3^- (mg/L)	SO_4^{-2} (mg/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	pH
Primaqua	24	16.12	63.66	1.18	77.66	42.7	93.52	4.07	–	–
Melliti	86	14	47	0.8	49	277	26	32	–	–

NB: (–) Values not available.

Table 3 | Descriptive statistics of the chemical characteristics of the selected Algerian water brands

							Confidence Limits (95%)	
Chemical elements	Symbol	Mean	Min.	Max.	Standard deviation	CV (%)	Lower limit (LL)	Upper limit (UL)
Hydrogen potential	pH	7.25	6.8	7.8	0.24	3.30	7.16	7.34
Calcium	Ca^{+2} (mg/L)	81.30	8	136	29.80	36.65	70.64	91.79
Magnesium	Mg^{+2} (mg/L)	28.58	3	75	16.48	55.66	22.68	34.48
Sodium	Na^{+} (mg/L)	44.01	5.5	145	32.74	74.39	32.29	55.73
Potassium	K^{+} mg/L)	2.16	0.35	8	1.58	73.18	1.59	2.72
Chlorides	Cl^{-} (mg/L)	63.47	2	170	42.14	66.39	48.39	78.55
Bicarbonates	HCO_3^- (mg/L)	269.09	24.4	617	119.43	44.38	226.35	311.83
Sulphates	SO_4^{2-} (mg/L)	84.03	1	210	57.68	68.64	63.39	104.67
Nitrates	NO_3^- (mg/L)	13.37	0.42	50	12.20	91.27	9	17.74
Nitrites	NO_2^- (mg/L)	0.01	0	0.1	0.02	171.48	0.004	0.019

between the medians and the maximums for most Algerian bottled waters. Relatively marked distinctions in terms of content are observed, particularly for Mouzaia and Righia. These results prove that the concentration rate of retained mineral waters varies strongly from one element to another and from one brand to another.

Physicochemical parameters of bottled water

Calcium: Its levels in Algerian bottled waters range from 8 (mg/L) (Righia) to 136 (mg/L) (Mouzaia). These waters are considered non-calcic with respect to the Algerian standards ($Ca^{+2} < 200$ (mg/L)) (Jora 2014). The variation of the calcium content (Figure 2(a)) shows the differences observed between the different mineral waters selected, 30% of the water brands exceed the upper limit of the confidence interval in terms of calcium concentration with values higher than 120 (mg/L), more particularly the two brands Mouzaia and Sidi Rached which are similar to the Tunisian water brand Aqualine. The water brands Apros (Switzerland), Vittel (France), and Garci (Tunisia) are very rich in calcium compared to Algerian waters. More than 33% of the Algerian water brands studied have very low calcium content, namely: Fezguia, Tazliza, Nestlé, Lala Khedidja, Ain Bougzel, Righia, Batna, Ledjdar, and Toudja. In addition, and from the point of view of calcium content, these waters correspond to the Cristaline (France), Sidi Ali and Ain Saiss (Morocco), and Sabrina and Primaqua (Tunisia) water brands.

Magnesium: Their contents vary between 3 (mg/L) (Righia) and 75(mg/L) (Mouzaia) and all meet the Algerian water potability standards ($Mg^{+2} < 150$ (mg/L)) (Jora 2014). Generally speaking, we note that more than 36% of Algerian water brands have very high magnesium content, namely: Mouzaia, Baniane, Saida, Batna, Messeriguine, Dahya, Guedila, Mansourah, Amane, Lejdar, and Hayet, respectively. Moreover, the percentage of water brands with low magnesium content is also 36%, this is the case of Lala Khedidja, Ain Bouglez, Ayris, Sidi Rached, and Righia which are the brands with the lowest magnesium content. It should also be noted that Mouzaia with very high magnesium content is similar to Apros (Switzerland) and Graci (Tunisia) (Figure 2(b)).

Sodium: All Algerian water brands are considered sodium free ($Na^{+} < 200$ (mg/L)) (Jora 2014), with sodium contents varying from a minimum of 5.5 (mg/L) (Lalla khedidja) to a maximum of 145 (mg/L) (Mouzaia). Indeed, only 20% of the mineral waters studied have sodium content higher than 50 mg/L, which is the case of Mouzaia, Amane, Djamila, and Hayet.

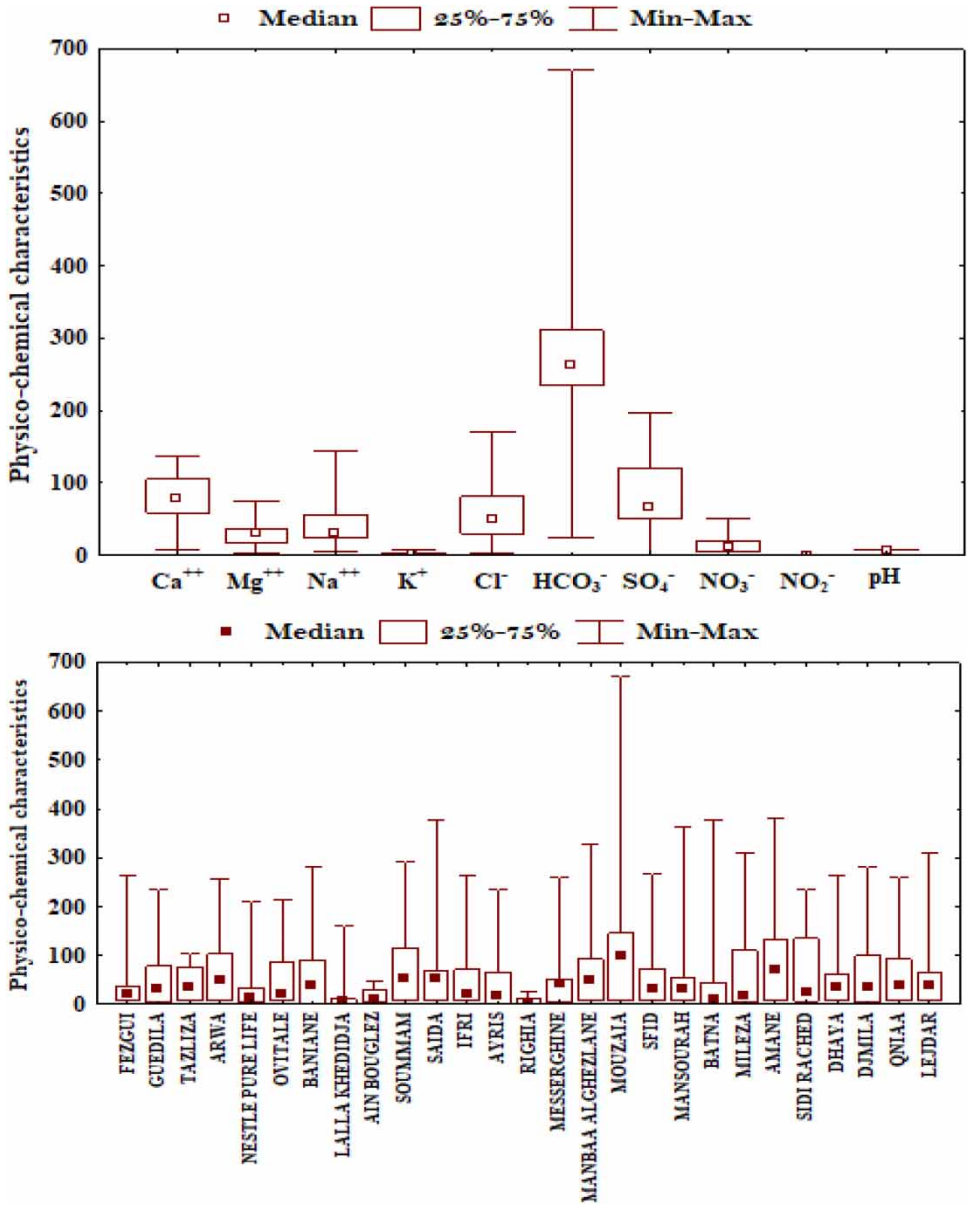

Figure 1 | Boxplot of the physicochemical characteristics of Algerian waters.

Furthermore, the mineral waters with the lowest sodium content ($Na + < 28$ (mg/L)) are respectively Fezguia, Nestlé, Lalla Khedidja, Ifri, Batna, and Righia (Figure 2(c)). In the same figure, it can be seen that, with the exception of Garci (Tunisia) which has a sodium content of 436 (mg/L), the other brands have moderate to low sodium contents, such as Apros, Evian, and Vittel.

Potassium: It can be seen that potassium levels are quite low for most of the Algerian mineral waters studied, they are between 0.35 and 8 (mg/L) and they respect the Algerian water potability standards set at 12 (mg/L) (Jora 2014). The brands of water with high or low potassium content are those that are outside the limits of the 95% confidence interval, below 1.59 and above 2.72 (mg/L) (Figure 2(d)). We also note that, with the exception of Garci (Tunisia) and Tazliza which have higher or lower potassium content (8(mg/L)), all the brands studied, whether Algerian, European, Moroccan, or Tunisian, have more or less similar potassium contents.

Chlorides: The selected waters are considered non-chlorinated and meet the maximum chloride content ($Cl^- < 500$ (mg/L)) (Jora 2014), with chlorides ranging from 2 (mg/L) (Batna) to 170 (mg/L) (Djemila). Through Figure 3(a), we

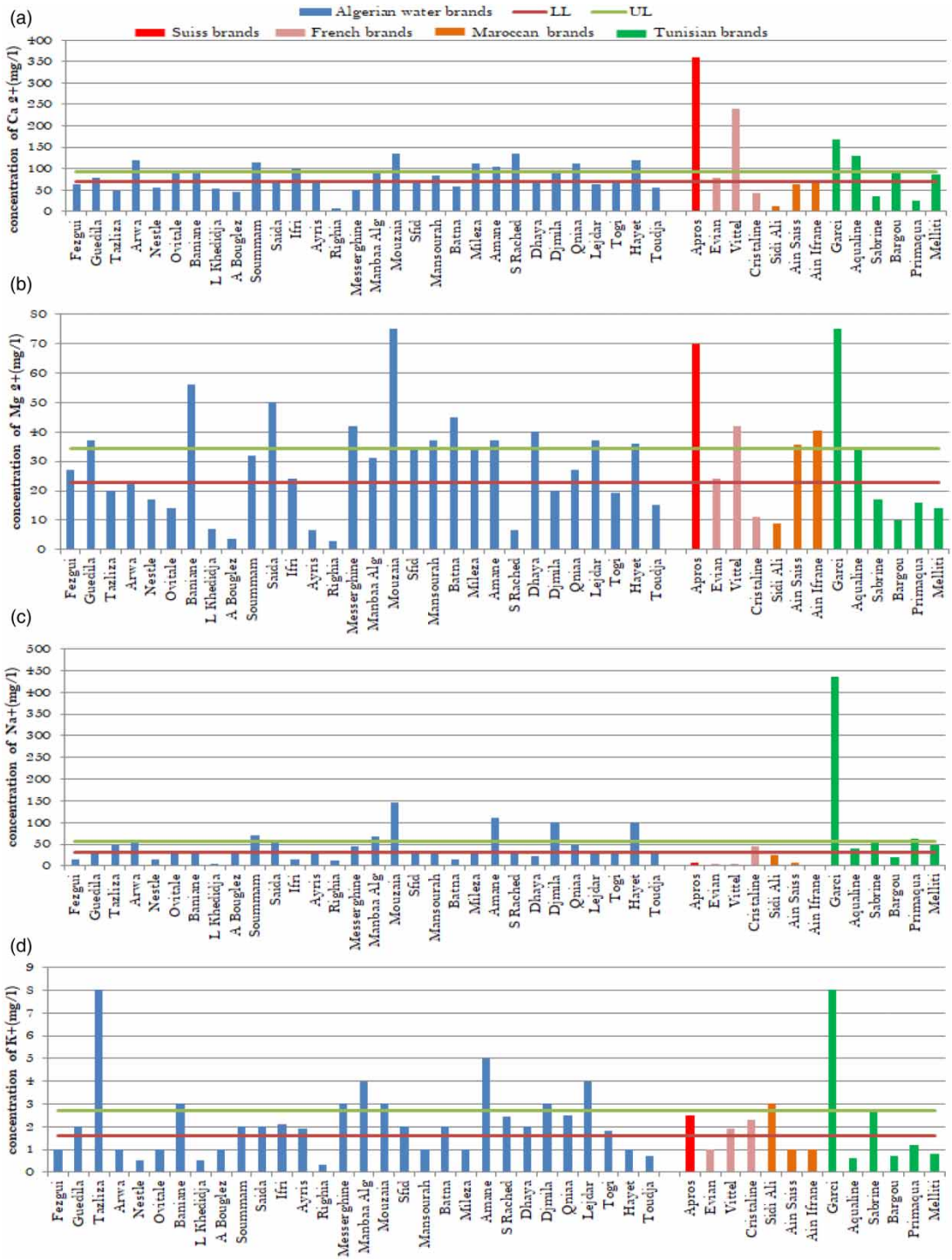

Figure 2 | Mineral water cations and confidence interval at 95%. (LL: lower limit, UL: upper limit).

notice that only 20% of the Algerian mineral waters can be considered as rich in chlorides with an amount that exceeds 80 (mg/L), namely: Djemila, Amane, Mouzaia, and Hayet. We also notice that, with the exception of Garci (Tunisia) which has a chloride content exceeding 300 (mg/L), the other brands, whether European, Moroccan, or Tunisian, have chloride contents comparable to those of the majority of Algerian water brands.

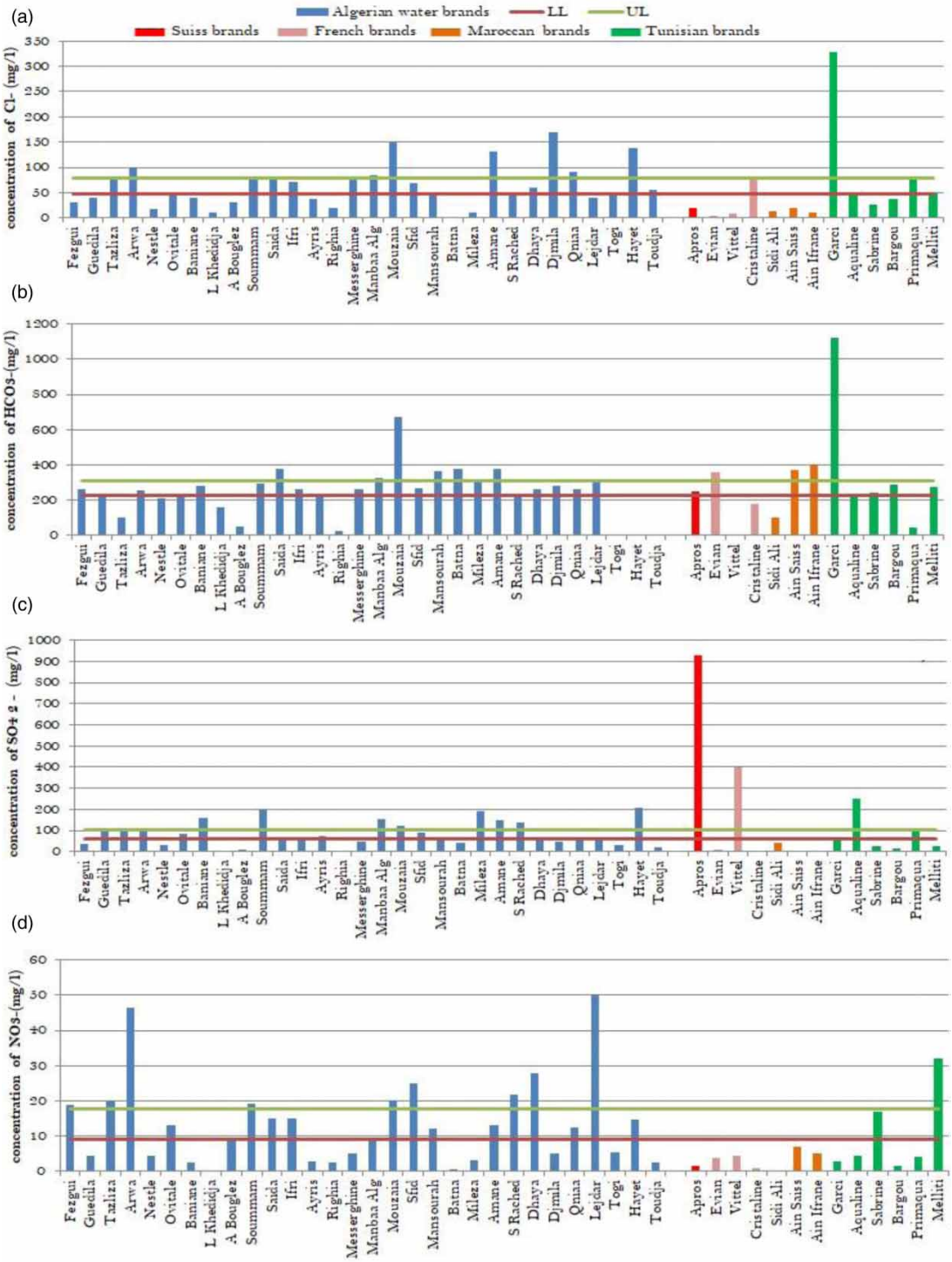

Figure 3 | Mineral water anions and confidence interval at 95%. (LL: lower limit, UL: upper limit).

Bicarbonate: The bicarbonate contents of the selected water brands range from 24.4 (mg/L) to 671(mg/L), which can be considered non-bicarbonated ($HCO_3^- < 600$ (mg/L)), with the exception of Mouzaia brand, whose bicarbonate content exceeds this threshold (Figure 3(b)). It should also be noted that, with the exception of Garci (Tunisia) which has very high bicarbonate content, the other foreign brands have contents of this element similar to the Algerian brands.

Sulphate: Sulphate concentrations in mineral waters range from 1 (mg/L) (Righia) to 210 (mg/L) (Hayet). These remain in compliance with the Algerian water potability standards which set the maximum sulphate concentration at 400 (mg/L) (Jora 2014). Referring to Figure 3(c), we can see that 26% of the Algerian water brands studied can be considered as rich in sulphates, namely: Hayet, Soummam, Mileza, Baniane, Manbaa Al Ghezlane, Amane, Sidi Rached, and Mouzaia. On the other hand, apart from some brands such as Apros, Vittel, and Aqualine (France) which have very high sulphate contents, the other foreign brands have contents very close to the Algerian mineral waters.

Nitrate: The different waters have nitrate levels varying from 0.42 (mg/L) (Lala Khedidja) to 50 (mg/L) (Ledjar), and very low nitrite levels with a maximum of 0.1 (mg/L). The concentrations of these nitrogenous compounds (nitrates and nitrites) remain in conformity with Algerian potability standards of 50 (mg/L) for nitrates and 0.2 (mg/L) for nitrites (Jora 2014). Figure 3(d) shows that 30% of Algerian waters have a nitrate content that exceeds the upper limit of the confidence interval (18 (mg/L)), namely: Lejdar, Dhaya, Sidi Rached, Sfid, Mouzaia, Arwa, Tazliza, Fezguia, and Soummam. On the other hand, the majority of the remaining Algerian water brands have very low nitrate content, which is the case of all the foreign water brands except the two Tunisian brands Sabrine and Melliti.

Referring to Table 4 which presents the classification of the Algerian water brands retained according to the predominant chemical element, we note that Nestlé, Lala Khedidja, Ain Bouglez, and Righia are weakly mineralized waters. However, Mouzaia and Amane are highly mineralized waters.

Furthermore, the water brands Arwa, Soummam, Ifri, Mouzaia, Meliza, Amane, Sidi Rached, Hayet, Qniaa, and Djemila are calcium-rich waters. These brands are recommended to prevent and fight osteoporosis, for people who consume little dairy products, during pregnancy to increase fetal calcium accretion and to prevent maternal bone calcium loss, and for

Table 4 | Summary of the characteristics of all the selected brands of water according to their content of chemical elements

Chemical Characteristics / Water brands	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-2}	NO_3^{-}
Fezguia	P	M	P	P	P	M	P	R
Guedila	M	R	P	M	P	M	M	P
Tazliza	P	P	M	R	M	P	M	R
Arwa	R	M	M	P	R	M	M	R
Nestle Pure Life	P	P	P	P	P	P	P	P
Ovitale	M	P	P	P	M	P	M	M
Baniane	M	R	P	R	P	M	R	P
Lalla Khedidja	P	P	P	P	P	P	P	P
Ain Bouglez	P	P	P	P	P	P	P	P
Soummam	R	M	R	M	M	M	R	R
Saida	P	R	M	M	M	R	M	M
Ifri	R	M	P	M	M	M	M	M
Ayris	P	P	P	M	P	M	M	P
Toudja	P	P	P	P	M	N	P	P
Messerghine	P	R	M	R	M	M	P	P
Manbaa Al Ghezlane	M	M	R	R	R	R	R	M
Mouzaia	R	R	R	R	R	R	R	R
Sfid	M	M	P	M	M	M	M	R
Mansourah	M	R	P	P	P	R	M	M
Batna	P	R	P	M	P	R	P	P
Mileza	R	M	P	P	P	M	R	P
Amane	R	R	R	R	R	R	R	M
Sidi Rached	R	P	P	M	M	M	R	R
Dhaya	P	R	P	M	M	M	M	R
Hayet	R	R	R	P	R	N	R	M
Qniaa	R	M	M	M	R	M	M	M
Togi	P	P	P	M	P	N	P	P
Righia	P	P	P	P	P	P	P	P
Djmila	R	P	R	R	R	P	P	P
Lejdar	P	R	P	R	P	M	M	R

NB: R (water rich in this element), M (water has an average content of this element), P (water poor in this element), **N** (deficiency).

dieters (Ordé 2019). Calcium waters are not recommended for people with kidney problems such as stones and renal colic (Queneau & Jacques 2006; Fredot 2007).

However, the brands rich in magnesium are Guedila, Baniane, Saida, Messerghine, Mouzaia, Mansourah, Batna, Amane, Dhaya, Hayet, and Ledjar, respectively. These waters can be proposed to fight against fatigue, reduce anxiety, and treat constipation (Ordé 2019). Magnesium water is also not recommended for pregnant women because of its laxative effect (Fredot 2007). Soummam, Manbaa Al Ghezlane, Mouzaia, Amane, Hayet, and Djmila brands are rich in sodium. These waters are therefore useful in case of diarrhoea, dehydration, or hot weather. They control digestive disorders (antacid effect), regulate the blood, favour sports effort, and limit the appearance of muscle cramps. On the other hand, they are not recommended in case of arterial hypertension, water retention (formation of oedema), infants, or other pathology justifying a low salt diet. In case of high blood pressure, it is better to consume low sodium waters such as Lala Khedidja, Ain Bouglez, Righia, or Nestlé.

Waters rich in potassium (Tazliza, Baniane, Messerghine, Manbaa Al Ghezlane, Mouzaia, Amane, Djemila, and Lejdar) can therefore regulate muscle contraction (avoid cramps) (Fredot 2007).

Among the waters rich in chlorides, we distinguish the brands Arwa, Manbaa Al Ghezlane, Mouzaia, Amane, Hayet, Qniaa, and Djemila, these waters are not recommended for salt-free diets, cardiac patients, and those suffering from kidney failure, but they do promote growth in children.

The mineral waters of Saida, Manbaa Al Ghezlane, Mouzaia, Mansourah, Batna, and Amane, which are rich in bicarbonates, can then be indicated to people suffering from difficult digestion and kidney stones in order to alkalize the urine. They are also recommended for sportsmen and women during a physical activity. Water rich in carbonates is not recommended for salt-free diets, heart disease, or high blood pressure (Queneau & Jacques 2006).

Waters rich in sulphates are Baniane, Soummam, Manbaa Al Ghezlane, Mouzaia, Mileza, Amane, Sidi Rached, and Hayet. They are recommended in case of constipation. However, these waters can present risks of gastrointestinal irritation, and abuse of these waters can, paradoxically, lead to dehydration (Fredot 2007). Only the brands Arwa, Sfid, Sidi Rached, Dhaya, and Lejdar may be considered rich in nitrates which is not suitable for infants and people with cancer (Idrissi 2006; Phaneuf 2007).

Classification and characterization of water marks

The hierarchical classification dendrogram (Figure 4) of the branded waters shows that the 30 objects were classified according to visual inspection into three main water groups. The first and third groups consist of nine and six mineral water brands, respectively, while the second group comprises half of the number of water brands studied. The waters in the third group are more highly mineralized (very rich in mineral salts) than the waters in the second group (moderately mineralized) and the first group, which are poor in mineral salts.

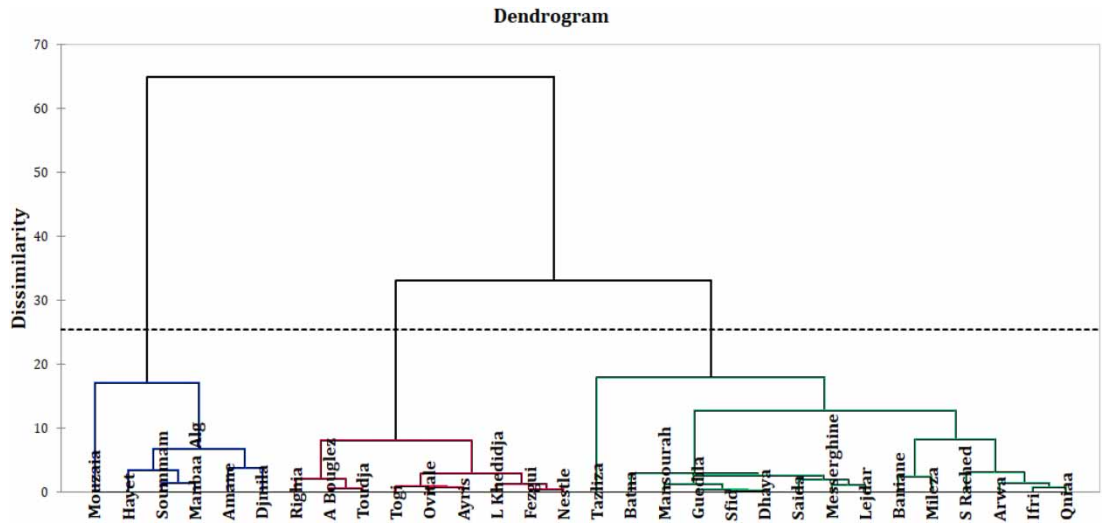

Figure 4 | Hierarchical classification dendrogram of selected Algerian water brands.

In order to better describe and visualize the results of the HAC, the same data matrix was subjected to PCA. The purpose of this statistical method is to characterize the variations in mineral salts for the different water brands. The results of the PCA show that the cumulative percentage of variance explained by the three selected principal components is 82.81%, which is quite good and can be used to identify the main chemical variations of the water brands in a three-dimensional space (F1, F2, and F3). These factors explain 54.21, 15.17, and 13.41% of the total variance, respectively (Table 5).

Examination of Table 6 indicates the existence of positive and negative correlations. The correlations between the variables and the three factors show the good representativeness of all the chemical elements with communities that vary between 72 and 90%. The first axis is positively and significantly correlated with all the variables except the major element K^{+}. The latter can be explained as an axis of richness in ions, especially Na^{+} and Cl^{-} in the first place, in second place Ca^{+2}, HCO_3^{-}, SO_4^{2-}, and finally Mg^{+2}.

Figures 5 and 6 show the projection of the three groups of waters described by the HAC onto the factorial plans (1–2) and (1–3) with an explained variance of over 67%. These figures distinguish the eccentric position of the first and third groups, and the clearly central position of the second group. Table 7 shows the three groups of waters resulting from this classification. The first group represents 20% of the population (Soummam, Manbaa Al Ghezlane, Mouzaia, Amane, Djemila, and Hayet). These waters are characterized by very high contents of chemical elements (Na^{+2}, Cl^{-}, Ca^{+2}, HCO_3^{-}, SO_4^{2-}, and Mg^{+2}), with the exception of Mouzaia brand, which is very mineralized compared to the other brands. The second group of 50% of the studied population is distinguished from the first group by its average mineralization (Guedila, Tazliza, Arwa, Baniane, Saida, Ifri, Messerghine, Sfid, Mansourah, Batna Mileza, S. Rached, Dhaya, Qniaa, and Lejdar). Nevertheless, in this group, Tazliza brand has very high K^{+} content. The third group, i.e. 30% of the total population, is made up of water brands with low mineralization (Fezguia, Nestlé, Ovitale, L. Khedidja, A. Bouglez, Ayris, Righia, Togi, and Toudja).

CONCLUSION

The main objective of the present work was to classify 30 brands of the most commercialized and consumed waters in Algeria into more or less homogeneous groups or categories according to their mineral content, using a combination of two statistical approaches, PCA and HAC; then, the comparison of these mineral waters with other regional and European water brands.

The results obtained showed that some Algerian water brands are similar to foreign brands in terms of mineral content. On the other hand, the combined HAC and PCA analysis revealed three groups of water with a very distinct mineralization. The

Table 5 | The factors selected by PCA

Factors	F1	F2	F3
Eigenvalue	3.795	1.063	0.939
Variance (%)	54.213	15.179	13.418
Cumulative variance (%)	54.213	69.392	82.810

Table 6 | Correlations between variables and factors

Chemical parameters	F1	F2	F3	Communities
Ca^{+2}	0.789	−0.188	0.494	0.901901
Mg^{+2}	0.701	−0.35	−0.485	0.849126
Na^{+}	0.891	0.193	−0.02	0.83153
K^{+}	0.422	0.726	−0.35	0.82766
Cl^{-}	0.806	0.325	0.033	0.75635
HCO_3^{-}	0.751	−0.484	−0.329	0.906498
SO_4^{2-}	0.705	0.024	0.478	0.726085

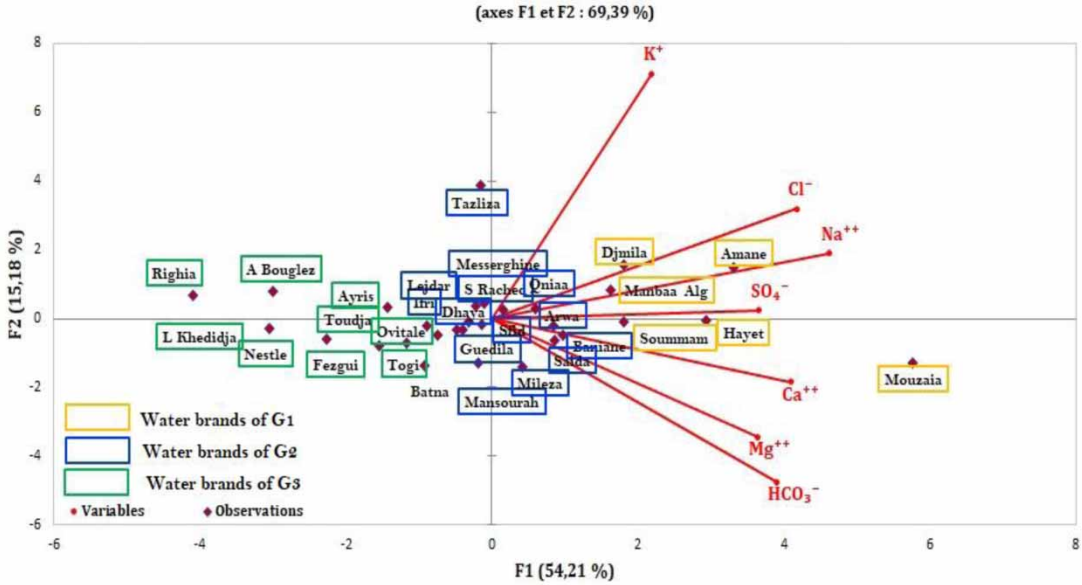

Figure 5 | Presentation of variables and observations in the plans (F1, F2).

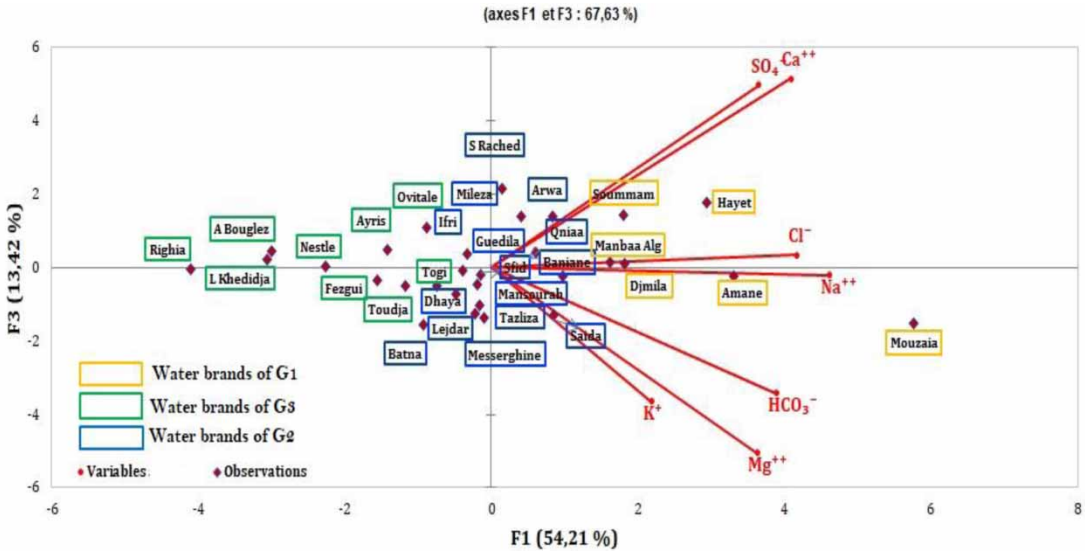

Figure 6 | Presentation of variables and observations in the plans (F1, F3).

first group formed by the brands (Soummam, Manbaa Al Ghezlane, Mouzaia, Amane, Djmila, and Hayet), these waters with a high mineralization are recommended for athletes and persons with mineral salt deficiencies. The second group formed by Guedila, Tazliza, Arwa, Baniane, Saida, Ifri, Messerghine, Sfid, Mansourah, Batna Mileza, S. Rached, Dhaya, and Qniaa et Lejdar, these brands of light waters can be consumed by everyone daily. The third group formed by Fezguia, Nestle, Ovitale, L. Khedidja, A. Bouglez, Ayris, Righia, and Togi et Toudja of low mineralized waters are recommended for infants and children.

The quantitative and qualitative classification obtained through this study does not favour any brand of water over another. In fact, all the brands of water respect the recommendations required by the Algerian regulations and remain in conformity

Table 7 | Interpretation of groups according to mineralization

	Water brands	Classification
Group 1	Soummam, Manbaa Al Ghezlane, Mouzaia, Amane, Dejmila, and Hayet	*Highly mineralized waters*: Rather rich in Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{-2} and medium rich in K^{+}
Group 3	Fezguia, Nestlé, Ovitale, L. Khedidja, A. Bouglez, Ayris, Righia, Togi, and Toudja	*Low mineralized waters*
Group 2	Guedila, Tazliza, Arwa, Baniane, Saida, Ifri, Messerghine, Sfid, Mansourah, Batna Mileza, S. Rached, Dhaya, Qniaa, and Lejdar	*Medium mineralized waters*: This group can be divided into two subgroups. The water marks above the first factor form the first subgroup and the others form the second subgroup. The waters of the first subgroup are rather very rich in K^{+} and moderately to weakly rich in Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{-2}. For the second subgroup, they are rather low in K^{+} and medium to low in Ca^{+2}, Mg^{+2}, Na^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{-2}.

with the standards. The main interesting result of this study is to allow nutrition specialists and bottled water consumers to expand the range of choices of brands with similarities in terms of chemical composition according to the physiological state of consumers. That is, the patient can select, for example, the water most suited to the health state among those belonging to the same category of bottled waters, characterized by similar or very close compositions in mineral elements.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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