RESEARCH ARTICLE

Evaluation of Chemical Content and Phytochemical Composition of Yemeni Almond Cultivars

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Abstract

The almond plant is considered one of the most important agricultural crops economically, nutritionally, and healthily, its properties and chemical composition differ according to the places of its cultivation. This study aims to estimate the chemical and phytochemical content of some local cultivars of almonds in Yemen. The chemical components, minerals, and secondary metabolites were estimated in the seeds. The results of the chemical analysis showed that the studied cultivars of Yemeni almonds contained a high percentage of nutrients compared to the imported samples, the percentages of moisture, protein, fat, carbohydrates, and ash were 2.88–3.39%, 12.7–19.15%, 36.87–65.34%, 13.23–38.02%, and 2.55–3.56%, respectively, and they contained a high content of some minerals such as iron, zinc, copper, and potassium. The total phenols in the studied almond cultivars ranged from 9.9–113 mg Gallic acid/g, and the total flavonoids ranged from 47.7–63.00 mg Rutin/g. It is concluded from the study that Yemeni almonds are characterized by unique properties that promise multiple uses in the food and pharmaceutical industries and in the prevention and treatment of many diseases.

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Introduction

The seeds of the almond plant are one of the nuts, which are a source of high nutritional value, whether for macronutrients (protein, fat, and carbohydrates) or micronutrients (minerals and vitamins), in addition to other vital compounds such as secondary metabolites, including phenolic acids, flavonoids, tannins, and alkaloids (Moshfegh et al., 2007; Lichtenstein et al, 2006; Sabate et al, 2006; Cesarettin et al, 2009). Almonds *Prunusdulcis* have great health and nutritional benefits, as they are a source of protein, polyunsaturated fatty acids, fiber, vitamin E, riboflavin, and essential minerals, in addition to phytosterols and polyphenols (Sylvia et al, 2013). Consuming almonds regularly has many health benefits, especially for heart disease, obesity, high blood pressure, and diabetes (Davide et al, 2020), in addition to having an antioxidant effect for cancer and atherosclerosis (Ivo et al, 2020), and plays a role in enhancing immunity and anti-inflammatory properties (Rabadán et al, 2019). The high nutritional value of the almond kernel stems mainly from its high content of fat, which is an important source of calories. Despite this, it does not contribute to raising blood cholesterol due to its high content of unsaturated fatty acids (Rafel et al, 2017). The seeds of the almond plant are one of the nuts that are a source of high.Almonds are also considered one of the most produced nuts in the world, as the amount of production worldwide reached 1.2 million tons in 2017. The US state of California is the most productive region, with almond production reaching about 81% of global production, followed by Australia by 7%, Spain by 4%, Iran by 1%, and Tunisia by 1% (Lillian et al, 2019). Almonds were cultivated in the Middle East 4000 years ago, and sweet almonds are an important and valuable specialty crop grown in many temperate and subtropical regions of the world. South Australia and the United States of America (Nizam et al, 2007).

In Yemen, almonds are one of the most important economic and monetary crops, and one of the most important crops competing with Qat is that its economic yield is high due to its high price which is a very large difference compared to imported almonds, due to its high quality, and it is considered one of the most important crops that qualify for expansion in its consumption and export level as a type due to its high quality. And its great competitiveness in the domestic and foreign markets. Moreover, its requirements are low as it can be successfully grown in marginal lands and under the rainfed system in areas with an annual rainfall of 200–300 mm or more under rain harvesting systems. Almonds are grown in Yemen on an area of 5,986 hectares, which represents 7% of the area cultivated with fruit crops. Its cultivation is mainly concentrated in Sana'a Governorate, with an estimated area of 5,959 hectares. It is also grown in both the governorates of Dhamar and Taiz, and the production reached 10,483 tons during 2018. (AASB, 2018). And the fact that pollination in almonds is mixed, the seed multiplication leads to the production of wide genetic variations, as there are many cultivars of almonds spread in Yemen, including pure cultivars bearing local designations that differ among themselves in quality, in phenotypic traits, and in environmental needs. Almond cultivars also vary in their content of chemical compounds or minerals due to genetic factors as well as different environmental conditions and agricultural treatments, in addition to the ripeness of the fruits at harvest time (Davide et al, 2020), and this is the most important factor affecting quality. The lack of a taxonomic key and a national record for the different varieties or breeds to preserve the rights and the national identity of these varieties/cultivars, especially for a national crop such as almonds, is one of the most important problems that should be overcome. In addition to that, the scarcity of studies and research concerned with characterizing the local genetic origins of almonds, whether phenotypic, chemical, or molecular characterization, as well as the scarcity of studies and research concerned with studying the chemical content of Yemeni almonds and whether the chemical content of Yemeni almonds is richer than others in compounds and minerals and has earned it high quality, so such The studies may contribute significantly to the issue of promoting and enhancing the competitiveness of Yemeni almonds locally and regionally. Therefore, this study aimed to characterize the phenotypic traits and estimate the chemical and mineral content and phytochemical composition of the most famous cultivars of Yemeni almonds.

Materials and Methods

Study area and sample resources

The study was conducted during the months of June and July 2021, and plant tree samples were studied in the two regions of Khirbet Mohib in BaniMatar District and Jabal Al Lawz in Khawlan District, Sana'a Governorate, Yemen. The most prevalent cultivars were identified in the two regions with the help of almond farmers in the studied areas; three cultivars were identified in the BaniMatar region and six cultivars in the Khawlan region. The sources, geographical location data, and local names of the studied samples are listed in Table 1.

Table 1. The sources, geographical location data and the local names of Almond samples

Sample No	Cultivars Local name	District	Region	Height (m)	Geographical location	
					longitude	Latitude
1	Large fit Razky	BaniMatar	Khirbet Mohib - Jabal al-NabiShuaib	2877	43.98916	15.32038
2	Middle Razky		Khirbet Mohib	2853	43.98186	15.3121
3	Small Raziki		Khirbet Mohib	2814	43.2036	15.31213
4	Large Razky	Khawlan	Murbk - Jabal Al-Lawz - Al-Tayyal	2684	44.2867	15.2334
5	Twined Jelly		Murbk- tayyal	2664	44.88634	15.23383
6	Shahty		Murbk- Jabal Al-Lawz - Al-Tayyal	2691	44.28669	15.2339
7	Rounded Razky		Murbk- Jabal Al-Lawz - Al-Tayyal	2687	44.2871	15.2337
8	FlatRazky		Murbk- Al-tayyal	2677	44.28635	15.2339
9	Oblong Razky		Murbk- Al-tayyal	2691	44.28713	15.23369

Almond seeds samples collection and preparation

Nine samples of almond seeds, each weighing 1 kg of almonds, were collected from each of the identified trees. They were kept in sterile polyethylene bags, then transported to the laboratory, peeled, and kept in sterile polyethylene bags at 4 °C until use, and it was transported to laboratories and preserved in the same way for chemical analysis. Almond seed samples were ground and preserved in sterile polyethylene vacuum-sealed bags in the dark at 4°C and used for analysis on the same day. The local cultivars used in this work (Fig. 1)

Figure 1. The variation of the studied cultivars of almonds in some of the phenotypical characteristics of the almond: 1) large fit Razky, 2) Medium Razky, 3) Small Razky, 4) Large Razky, 5) Rounded Gly, 6) Shahty, 7) Rounded Razky, 8) Flat Razky, 9) A oblong Razky

Chemical analysis

Estimation of the chemical composition of almond seed samples

The almond seed content of moisture, protein (Keldahl method), total fat (Sacholite method) and ash were estimated the Association of Official Analytical Chemists AOAC methods (AOAC, 1997; Al jawfi et al, 2014; Al jawfi et al, 2013; AOAC, 2000).

Determination of the mineral content of almond seeds

Minerals (Ca, Mg, Na, Al, Fe, Cu, Zn, Mn and Boron B) were determined in almond seeds using ICP emission spectrometry according to the method used by the Association of Official Analytical Chemists AOAC No. 985.01 (Al jawfi et al, 2014).

Samples extraction and preparation for phytochemical analysis

The cold method extraction method was used for each samples, 50 grams of seeds were milled, then it was extracted by 250 ml of methanol for 24 hours with continuous shaking, then the extracts were filtered by Waterman paper No. 4, and the solvent was removed using an Rotary evaporator at 40 °C, the extracts then were kept at 5 °C until the total phenols and flavonoids determination (Al jawfi et al, 2014).

Determination of the phytochemical content of almond seeds

Secondary metabolite compounds (total phenols and flavonoids) were determined in almond seed extracts.

Determination of Total phenols

Total phenols were determined by folin-Cioclteu reagent colorimetric method (BinMowyna and Alsayadi, 2020: Al jawfi et al, 2014; Al jawfi et al, 2013; Makkar, 2003). Briefly 1 ml of sample extract (0.1%, w/v), 0.5 ml Folin–Ciocalteu reagent (1:2 v/v), 2 ml of 5% sodium carbonate were vortexed and allowed to stand at 30°C for 1 h. Absorbance was measured with a UV-VIS spectrophotometer at a wavelength of 765 nm. The total phenolic content of Almond extracts was expressed as Gallic acid equivalents per g of dry weight (mg GAE/g).

Determination of Total flavonoids

The Total flavonoids contents TFC of the samples was determined using the aluminum chloride method that previously described (Lujain et al, 2022) with few modifications, briefly, the sample extract (1.0 gm) was mixed with distilled water (4 ml), followed by sodium nitrite (0.3ml) and after 5 min, aluminum chloride (3ml) solution was added, and after 6 min, NaOH (2 ml, 1.0 M) and distilled water (10 ml) were added at 25°C. The absorbance was determine by a spectrophotometer at 510 nm. The results were put as rutine equivalents (mg RE/ g sample).

Statistical analysis

The mean, standard deviation, and correlation coefficient for the results of the chemical and phytochemical composition of almond seeds were estimated, and ANOVA was estimated using One Way ANOVA and Tukey Tests, and significant differences were calculated at the level of P≤0.05 using SPSS V. 21.

Results and discussions

Chemical content

Basic chemical compounds

Table 2 shows the chemical composition of the studied almond samples. It is noted that the moisture content ranged from 2.88% for the sample of Small Razaki to 3.39% in the sample of "Shahty", This result is consistent with what was found by Nizam et al. (2017) while studying samples of Turkish almonds. It should be noted that the humidity rate is suitable for preserving almond kernels for long periods. On the other hand, the protein content ranged from 12.7% in a sample of flat Razaki almonds from the Khawlan region to 19.57% in a sample of large proportionate Razaki from BaniMatar region, and these results are considered less than what was found by Nizam et al. (2017) in Turkish almond samples and Sylvia et al. (2013) in samples of American almonds from California, both of which reached about 20%. In contrast, these results are consistent with what was found by Drogoudi et al. (2013) when studying samples of Greek almonds, where it ranged between 10-29%, while Ruggeri et al. (1998) and Drogoudi et al. (2013) found that the percentage of protein in Italian almond samples ranged between 16-25%, and Riquelme et al. (1985) that the percentage of protein in Spanish almond samples ranged between 15.7-21.1%, and in a study conducted by Pavlinad et al. (2012) on different almond samples from France, Italy, and Greece, the protein content ranged between 10-29%. This was indicated by Ruggeri et al. (1998), Sathe (1993), and Drogoudi et al. (2013) indicated that the chemical composition has an important role in the difference between almond samples in protein ratios.

Table 2. Chemical content of protein, total fat, ash and carbohydrates of the studied almond cultivars

almond cultivars	Moisture%	Protein (N×5.18)%	Total Fat%	Total Ash%	Carbohydrates%
Large fit Razky	3.38±0.05	19.57±0.30	44.88± 1.05	3.2±0.01	28.97±1.25
Middle Razky	3.39±0.04	17.6±0.78	37.95±1.02	3.56±0.95	37.46±1.73
Small Raziki	2.88±0.12	15.97±0.83	56.46±1.06	3.02±0.95	21.65±0.99
Large Razky	3.44±0.05	19±0.81	36.87±1.11	2.7±0.02	38.02±1.98
Twined Jelly	2.91±0.05	14.6±1.77	43.84±1.30	2.55±0.01	36.09±0.47
Shahty	3.73±0.06	18.88±0.43	53.53±1.09	3.27±0.33	20.57±0.81
Rounded Razky	3.27±0.05	16±0.2	64.71±1.13	2.84±0.03	13.23±0.90
Flat Razky	2.92±0.02	12.7±0.51	65.34±1.15	2.7±0.01	16.18±0.73
Oblong Razky	2.95±0.01	15.64±0.15	52.55±0.67	2.68±0.02	26.18±0.73

From the results in Table 2, it is clear that the percentage of fat varied between the different samples, as it ranged from 36.87% in the Large Razqi from the Khawlan region to 65.34 and 64.71% in each of the almond samples, Razqi flat and Razqi round, respectively. It should be noted here that there is a worldwide variation in the fat content of almonds, ranging between 25-67%. In a study conducted by Agar et al. (1998) on some samples of Turkish almonds, the fat content ranged between 25 and 65%, while in other studies on Spanish almonds, Garcı´a-Lo´pez et al. (1996), Garcı´a-Pascual et al. (2003), Kodad et al. (2006), Kodad and Sociasi (2008), Lo´pez-Ortiz et al. (2008), Romojaro et al. (1988), Sa´nchez-Bel et al. (2008), and Soler et al. (1988), the percentage of fat ranged between 40 and 67%, and in a study by Sylvia et al. (2013) on American almonds from California, the percentage of total fat ranged between 49 and 50%. It should also be noted that the high nutritional value of the almond kernel arises mainly from its high fat content, which is an important source of calories. Despite this, it does not contribute to raising blood cholesterol due to its high content of unsaturated fatty acids (Rafel et al, 2017).

As for the percentage of total ash, it ranged between 2.55% in the Jali Mabroum sample from the Khawlan region and 3.56% in the average Razqi sample from BaniMatar region (Table 2). These results agree with what was found by Barbera et al. (1994) and Ruggeri et al. (1998), where the percentage of total ash ranged between 2.3-3.7%. As for the carbohydrate content, it ranged in a relatively wide range between 13.24% in the sample of Razqi Medawar and 38.02% in the sample of Razaki Kabeer, as shown in Table 2, and by comparing these results with the results of other studies, Barreira et al. (2012) found that the percentage of total carbohydrates ranged from 14% to 21%, while Ahrens et al. (2005) found in another study that the proportion of carbohydrates reached between 23.5 to 27%, as also found Akpambang et al. (2008) that the proportion of carbohydrates up to 28%.

Mineral contents

Table 3 shows the results of mineral analysis in the studied almond cultivars.It is noted that the highest value was in the cultivars of Razqi large, which originated from the Khawlan region, where it amounted to 6.207 mg/100 grams, followed by each of the cultivars of Razqi medium and Razqi small from BaniMatar region, which amounted to 5.419 and 5.003 mg/100 grams, respectively, followed by the two cultivars Razqi is a large matcher from BaniMatar and Shahti from Khawlan, with values of 3.572 and 3.415 mg/100 grams, respectively, and the previous values were higher than the value achieved by the control, which amounted to 3.378 mg/100 grams, while the lowest value for zinc content was in the Razqi sample. flat, reaching 2.814 mg/100 g. These results indicate that the zinc content of Yemeni almonds was high in three samples: large, medium, and small, while the rest of the samples were within the accepted range, according to international studies, which ranges between 2-4 mg/100 grams (Rafel et al, 2017). This is considered a comparative advantage for some types of Yemeni almonds over external almonds, which have a higher nutritional value and more health benefits.

The same is the case with regard to the content of the iron element in the samples. The highest value was found in a medium razqi sample, which came from BaniMatar, with a value of 7.261 mg/100 grams, followed by a small razqi sample from BaniMatar as well, then a rectangular razqi sample from Khawlan, with values of 6.622 and 5.001 mg/100 grams, respectively, compared to the lowest value in the Yemeni almond samples, which amounted to 4.221 mg/100 grams in the Jelly Mabroum sample. These results show that three samples of Yemeni almonds are medium razki, small razqi from BaniMatar, and oblong razqi from Khawlan. Their content of iron was higher than the accepted range in the results of international studies of external almond samples, which ranged between 2.6 and 4.9 mg/100 gram (Rafel et al, 2017).

As for the copper component, the highest samples in their copper content were a medium razqi and a small razqi, both from the BaniMatar region, where the values of their copper content were 1.844 and 1.731 mg/100 grams, respectively, followed by a matching large razqi sample from the BaniMatar region, also with a value of It amounted to 1.731 mg/100 grams, and these three samples were higher than the control sample, which amounted to 1.417 mg/100 grams, while the two samples of Razqi Round and Razqi Kabir were the least samples in their content of copper, as they reached 0.917 and 0.948 mg/100 grams, respectively. (Table 3). According to what was reported by Rafel et al. (2017), the copper content reported in many international studies ranged between 0.9 and 1.3 mg/100 g. From this, it is clear that Yemeni almonds are distinguished by their high content of copper compared to other types of almonds.

As for the manganese mineral, it is noted from Table 3 that its value ranged between 2.271 and 1.232 mg/100 grams in each of Shahti and Razqi flat, respectively. The studied was higher in copper content, except for flat razqi, jali twisted, and oblong razqi, all of which were from Khawlan region. As indicated by Rafel et al. (2017) regarding the recognized range of manganese, it ranges between 1.2 and 3.04 mg/100 g, and all studied samples were within this range.

Table 3. Content of studied almond cultivars of some trace minerals (zinc, iron, copper, manganese) in mg/100g

almond cultivars	Zn	Fe	Cu	Mn
	mg/100g			
Large fit Razky	3.572	4.393	1.731	1.735
Middle Razky	5.419	7.261	1.844	1.798
Small Raziki	5.003	6.622	1.765	1.913
Large Razky	6.207	4.969	0.948	1.883
Twined Jelly	3.196	4.221	0.974	1.611
Shahty	3.415	4.804	1.124	2.271
Rounded Razky	3.305	4.789	0.917	1.809
Flat Razky	2.814	4.429	1.142	1.232
Oblong Razky	3.303	5.001	1.081	1.585

With regard to the microelements in Table 4, the potassium content of the studied samples ranged between 2000 and 1130 mg/100 in each of the middle Razqi sample from the BaniMatar region and the rectangular Razqi sample from the Khawlan region, which was less than the control sample, which amounted to 1200 mg/100 grams, and it should be noted here that the content of the studied samples was higher than the range reported by Rafel et al. (2017), which ranges from 430 to 940 mg/100 g. As for the element calcium, the range was relatively narrow, as it ranged between 87.71 and 105.80

mg/100 grams for Razky Round and Razky Small, respectively. As for the magnesium element, it ranged between 428.76 mg/100 grams in the Razqi Medawar sample from the Khawlan region and 484.52 mg/100 grams in the middle Razqi sample from the BaniMatar region. These results are consistent with what was found by Davide et al. (2020). The content of the studied samples of the sodium element ranged between 37.8 and 52.05 mg/100 grams in each of Razqi Kabir from the BaniMatar region and Razqi Rectangle from the Khawlan region, respectively. It should be noted here that the sodium content in all the studied samples was high compared to what was mentioned by Rafel et al. (2017), where he showed that the range of sodium in the results of some studies ranged between 1 and 20 mg/100 g.

On the other hand, it is noted from the results shown in Table 4 that the content of the studied samples of the aluminum element ranged between 0.434 and 2.497 mg/100 grams in each of the samples of a large proportional Razqi from the BaniMatar region and a large Razqi sample from the Khawlan region, respectively. It is also noted that the boron content of the samples ranged between 1.398 and 5.055 mg/100 grams in each sample of a large proportional Razqi from the BaniMatar region and a rectangular Razqi from the Khawlan region, respectively. These results are not consistent with what was reported by Cesarettin et al. (2009), who found that almonds do not contain aluminum and boron, while Davide et al. (2020) found that in a study conducted on more than twenty types of almonds, the presence of aluminum and boron in one sample amounted to 0.39 and 1.85 mg/100 g, respectively.

Table 4. The content of the studied cultivars of almonds of some minerals (potassium, calcium, magnesium, sodium, aluminum, boron) in milligrams / 100 grams

almond cultivars	K	Ca	Mg	Na	Al	B
	mg/100g					
Large fit Razky	1608	93.35	477.7	52.05	0.434	1.398
Middle Razky	2000	98.88	484.5	48.3	0.807	2.001
Small Raziki	1840	105.8	478.8	49.3	0.709	2.078
Large Razky	1220	95.5	481.6	40.9	2.497	3.572
Twined Jelly	1200	97.55	436.2	46.7	1.418	2.169
Shahty	1430	93.44	473.7	44.1	0.632	2.826
Rounded Razky	1390	87.71	428.8	39.2	0.694	1.883
Flat Razky	1330	89.9	458.8	45.2	0.861	2.411
Oblong Razky	1130	100.64	450.8	37.8	0.888	5.055

Phytochemical compounds content

Table 5 shows that the content of total phenolic compounds in the samples ranged between 9.9 and 113 mg of gallic acid / gram extracted in each of the two samples of Razqi Flat from Khawlan region and RazqiSaghir from BaniMatar region, respectively. Comparing the local almond samples with the control, it is noted that there are five samples that mathematically outperformed the control sample: large razky, small razqi, large razqi, mabroum jelly, and oblong razqi. These results are consistent with what was found by Joao et al. (2008), where it ranged in the studied almond samples between 9.22 and 163.71 mg Gallic acid / gram of extract. Likewise, with regard to the content of flavonoids, it is noted from Table 6 that there were only two samples that contained these compounds, a sample of small Razqi and a sample of large proportional Razqi, both from the BaniMatar region, as they reached 63 and 47.7 mg rutin /gram, respectively, while the rest of the samples did not contain flavonoids. Table 5 also shows the percentage of extraction yield, where the highest extraction rate was in the samples of Razqi Flat and Jali Mabroum, which amounted to 8% as the highest value, while the lowest value was in each of the samples Razqi Medium, Razqi Small, and Razqi Large from BaniMatar, which amounted to 5%. This finding was similar to that found by Joao et al. (2008).

Table 5. The studied almond cultivars content of phenolic and flavonoid compounds and the yield of phenolic materials extraction

Almond cultivars	Total Polyphenols (mg GAE/g)	T Flavonoids (mg rutin/g)	Yeild
Large fit Razky	66.5	47.7	5.1
Middle Razky	26.5	-	5
Small Raziki	113	63	5
Large Razky	36.6	-	5.5
Twined Jelly	37.6	-	8
Shahty	18.4	-	5.5
Rounded Razky	9.9	-	7.1
Flat Razky	19	-	8.1
Oblong Razky	33.4	-	7.3

Results of cluster analysis for chemical content

A cluster analysis was carried out for the characteristics of the aforementioned 17 chemical components after giving each characteristic a score from 1 to 9. Figure 2 shows the results of the cluster analysis, where it is noted that the studied cultivars of almonds differ among themselves according to their variation in chemical content and their content of minerals, phenolic, and flavonoid compounds. The studied cultivars/samples were divided into two main groups. It is also noted that this corresponds to the collection area. The cultivars collected from the BaniMatar region formed one group, and the cultivars collected from the Khawlan region formed another group. This division achieved a high correlation coefficient of 0.9012 at a significant level. 0.011, and this is due to the existence of correlations between some chemical components, which are illustrated in Figure 3. The first group included the "BaniMatar cultivars group" of three cultivars: large compatible Razaki, medium Razaki, and small Razaki. This group was characterized by a higher content of both ash and protein. And carbohydrates, zinc, manganese, iron, copper, calcium, magnesium, sodium, potassium, phenolic compounds, and flavonoids, and a lower content in each of total fats, aluminum, and boron compared to the second group, "Khulan region group". It is also noted from Figure 2 that there is a discrepancy between the cultivars within the groups, as the Razqi medium cultivars is located at a greater distance than the other two cultivars within the first group as a result of its higher content of some elements, lower content of fats, lower content of phenolic compounds, and lack of flavonoids. On the other hand, the sample Razqi Kabir differed from the rest of the cultivars within the framework of the second group due to the fact that it contains more protein, carbohydrates, zinc, aluminum, boron, iron, and magnesium and contains less fat.

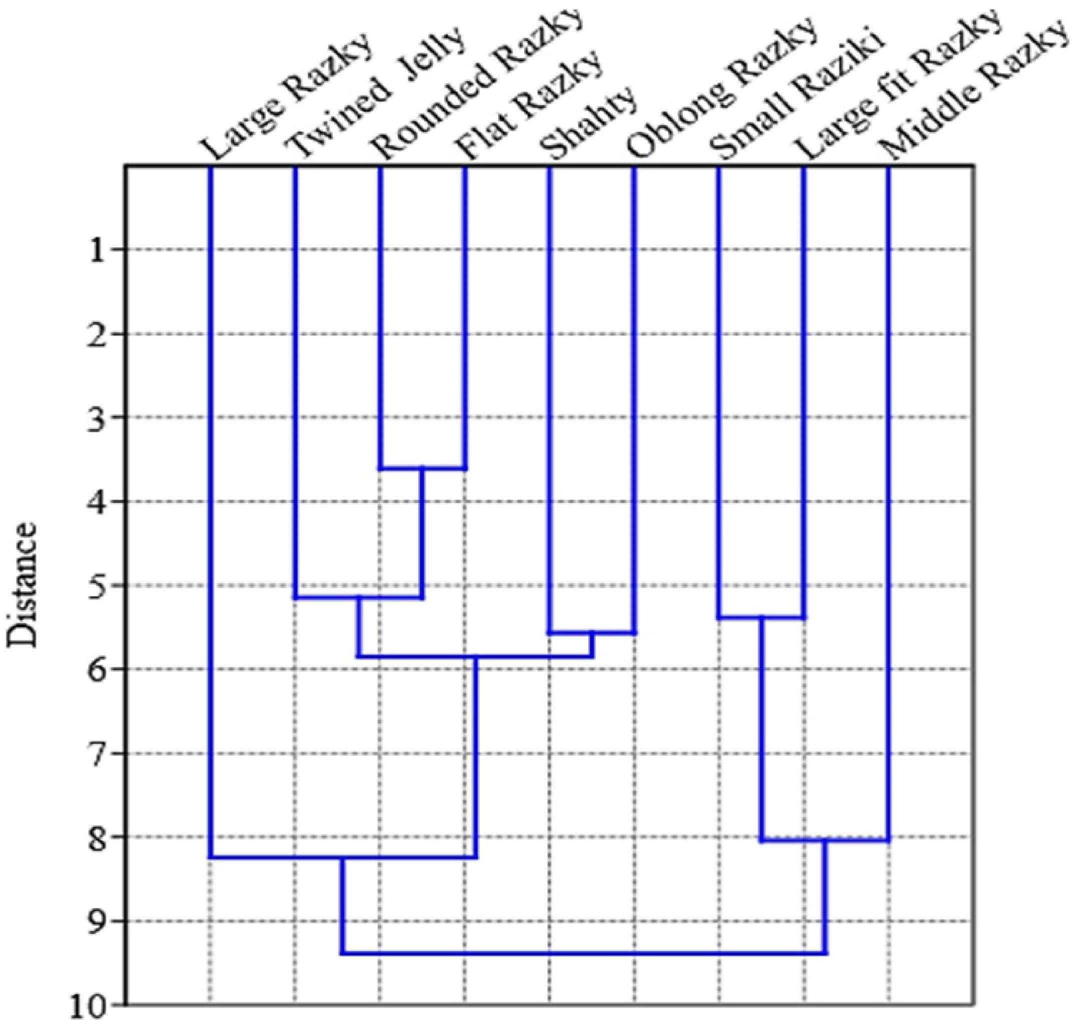

Figure 2. Tree of convergence or divergence between the studied cultivars of almonds according to their chemical and mineral content

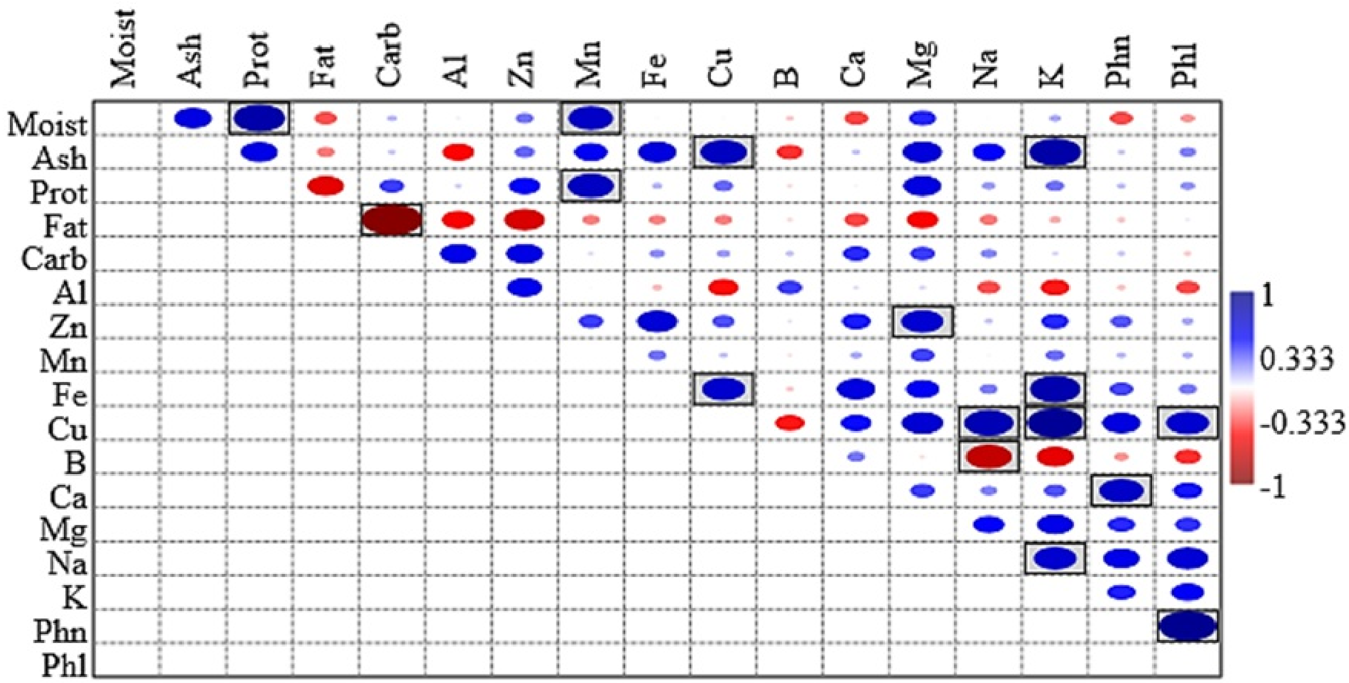

Figure 3. The correlation between the studied chemical components: the blue color is a positive correlation, the red color is a negative correlation, and the circles surrounded by a square mean that there is a significant correlation at a significant level of 0.05.

Through the results discussed previously, it is noted that there is no relationship between the results of the cluster analysis of the phenotypic traits and the results of the cluster analysis of the chemical and mineral content, as it is likely that most of the chemical components of the almond cultivars are greatly affected by the environmental factor and the crop management factor. The cultivars collected from the BaniMatar region seemed to be richer in their chemical content for most of the chemical components except for fats, aluminum, and boron. Perhaps this is attributed to the environmental factor as well as better crop management processes in the BaniMatar region, and this can be attributed to the intensity of interventions in the BaniMatar region, especially the recent interventions. Within the project of decentralizing water management in the Sana'a Basin, the BaniMatar district, especially the Khirbet Moheib area, was a center for the project's interventions, especially in the almond cultivation sector. However, training programs were accompanied by training programs for farmers in managing the almond crop, such as fertilization, irrigation, and various agricultural operations.

Conclusion

The results showed that the content of some studied cultivars of Yemeni almonds of some minerals such as zinc, copper, iron, and potassium was higher than the range known in international studies conducted on types of external almonds, which means that Yemeni almonds have a higher nutritional value and more health benefits compared to external almonds.

The studied cultivars of almonds varied among themselves according to their variation in chemical content and were divided into two main groups according to the collection region. The cultivars collected from the BaniMatar region were characterized by a higher content of ash, protein, carbohydrates, zinc, manganese, iron, copper, calcium, magnesium, sodium, potassium, phenolic, and flavonoid compounds, and the content was lower in each of the total fats, aluminum, and boron compared to the second group, "the group of cultivars of the Khawlan region".

Some types of Yemeni almonds have a higher nutritional and healthy value than the external types of almonds due to their high content of chemical components and minerals. Some of these benefits can be summarized as follows:

Yemeni almonds, in some cultivars, contain a high percentage of fat, up to 65%, and are an excellent source of energy. In addition, the quality of the fat present in almonds is of a beneficial type that lowers cholesterol in the blood and preserves the integrity of the heart and blood vessels from sclerosis.

The study showed that most of the almond cultivars contain a high percentage of minerals compared to studies conducted on other types of almonds worldwide.

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