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Comparing physicochemical properties and antioxidant potential of sumac from Iran and turkey

Abstract

Sumac is a medicinal plant that used as a spice. The sour red small epicarps of the fruit are applied in traditional medicine and cookery. In this study, some physical, chemical and antioxidant properties of its aqueous and ethanolic extracts of the sumac fruits of Iran were investigated. The average m1000, bulk density and porosity percentage ranged from 15.9-16.9g, 304.6-306.7 kg/m3 and 68.31-97.26%, respectively. The galvanized sheet with the lowest static friction coefficient was the best surface for the fruit transfer. The mean length, width, thickness and volume were in the range of 4.73-4.98mm, 4.08-4.54mm, 2.33-2.51mm and 17.64-22.46mm3, respectively and the mean sphericity coefficient varied from 0.73 to 0.76. This information is of great importance for the design of the equipment of harvest, transfer and processing of sumac fruit. This study also represent that the antioxidant activity, free radical scavenging and reducing capacity of the ethanolic extract were higher than those of the aqueous one. Moreover, the ethanolic extract had a larger total phenol and anthocyanin content as compared to the aqueous one.

Keywords: antioxidant, chemical, physical properties, sumac, DPPH

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Introduction

Spices and aromatic plants are utilized in the food industry, firstly because of the transfer of desirable flavor and aroma and secondly due to having antimicrobial activity which increases the shelf-life of foodstuffs.[1]

The Genus *Rhus* is comprised of more than 250species and are characterized well using phenolics and triterpenes. *Rhusglabra L.* was traditionally used by Indians, native to North America, to treat bacterial diseases such as Syphilis, Gonorrhea and diarrhea.[2] *Rhuscoriaria L.*, known as sumac, is another member of this genus which grows naturally in a vast district, from the Canary Islands (located in the Atlantic Ocean to the Mediterranean coasts, Iran and Afghanistan.[3,4]

Sumac (*Rhuscoriaria L*), a member of the Anacardiaceae family, is a small shrub with a height of 1-5m and leaves comprised of 9-15 leaflets which are jagged and covered with wool. It grows in warm and mild-weather regions.[5] The leaves color tends to be red in fall and it is one of the specifications of the plant.[6] Sumac has been used as a spice or medicinal plant during hundreds of years.[4] The applied part in traditional medicine and Iranian cookery are the sour red small epicarps of the fruit.[7]

Sumac is employed in the Iranian traditional medicine as an astringent, stancher and ant diarrheal agent. It is also used to eye trachoma, and to prevent the incidence of pox in eye.[3,8–11] The sumac spice is obtained from chopping the fruit of this plant and is used as a seasoning for kebab and various salads due to its sour flavor (pH=2.5) which is caused by the presence of citric acid and malic acid.[3]

Clinical, food-protective, antimicrobial and physicochemical properties of the sumac extract have been investigated in different researches.[12–22] Large amounts of tannins have been observed in the aqueous extract of the dried leaves of sumac (*R. coriaria L.*).[23] Recently, the superoxide radical scavenging activity.[24] and the mineral content of sumac leaf and fruit have been examined.[25] Recovery of the phenolic compounds from different solvents is influenced by the solvent polarity and the solubility of these compounds in the solvent.[26] The polarity range of polyphenols is widespread and consequently, a large number of solvents can be taken into account. Therefore, selection of a proper solvent for the extraction of the phenolic compounds from all samples is difficult.[26]

Different solvents and numerous extraction techniques can be applied in order to extract antioxidant compounds from plant tissues. The polarity degree of various solvents affects the extraction extent of polyphenolic compounds. The solubility of polyphenolic compounds differs, depending on the type of solvent, degree of polymerization and their interaction with other compounds present in plant tissues. Numerous studies have been carried out on the engineering properties of many seeds, including fenugreek, lentil, guan, cotton, coriander, flaxseed, pomegranate, cress, balangu, basil, plantain, sage, millet, cannabis, grain, sesame, quinoa and sumac.[25,27–40]

Engineering properties have a special importance in post-harvest processes.[41] For instance, the seed dimensions and shape influence the selection of the suitable sieve mesh. Angle of repose and frictional properties are used in the design of silos, storage tanks and conveyors. Although literature review shows that many researchers have been conducted on the physical properties of food and agricultural products and even on the sumac of other countries, no research has been performed up to now on the engineering properties of the Iranian sumac. Shape and size, bulk density, particle density, porosity, weight, static and dynamic friction coefficients are of the most important physical properties which are functions of moisture. The physical properties of agricultural products are needed for the design and manufacture of the equipment of transfer, processing, sorting, grading and qualitative assessment of such products.[42] In another research carried out by Özgüven F et al.[43] on the physical, mechanical and aerodynamic properties of pine nut, some properties, including the cracking force, frictional properties such as the static friction coefficient and the dynamic angle of repose of the seed, core

and crust were measured. These properties are useful for designing the equipment of processing, storage, hopper and handling.[43]

The aim of this study was to determine and investigate the physical properties, including the dimensions, m1000, particle density, bulk density, porosity and static friction coefficient, in addition to the chemical properties such as the chemical composition of the sumac fruits of Iran. We also aimed to measure the total phenol content, total anthocyanin content, reducing power and the DPPH free radical scavenging power of the aqueous and ethanolic extract of sumac Epicarp and seed and compare it with the sumac of Turkey and Syria.

Materials and methods

Materials

Sumac clusters were supplied from the gardens of Gonabad, Ferdows and Zoshk (Khorasan, Iran) and cleaned up manually and separated from other plant residues. The physical tests of the sumac seeds were performed at the moisture content of 5.0±0.2%. For the chemical tests, the fruits were ground into a coarse-particle powder using a pestle and mortar and separated from the seeds using a sieve. The epicarp and seeds were milled and passed through a 60 mesh screen. The separation performance of the epicarp and whole seed was calculated using the following equation:

$$separation efficiency\left(\%\right) = \frac{A}{B} \times 100$$

Where A represents the Epicarp and the whole seed, and B denotes the whole seed and the sumac clusters.

Physical properties

Dimensions: In order to determine the length, width and thickness of the sumac fruits, 50 seeds were selected randomly and their dimensions were measured with a caliper.

m_{1000} and particle density: In order to determine m_{1000}, 100 seeds were chosen randomly and weighed using a digital balance. m_{1000} was obtained through multiplying the measured mass by 10. The true density was measured through the pycnometer method using toluene. In this method, the true density (ρ_t) was calculated using equation (2).[32]

$$\tilde{n}_t = \frac{m}{V_t} \qquad (2)$$

Where m is the mass of the poured seeds (kg) and V_t stands for the volume of the displaced liquid (m³).

Bulk density and porosity: In order to determine the bulk density (ρ_b), the seeds were poured from a height of 15cm with a constant rate into a container with a certain volume. Then, the container was weighed and the bulk density was computed by equation (3):[32]

$$\tilde{n}_b = \frac{m}{V_b} \qquad (3)$$

Where m is the seed weight (kg) and V_b denotes the container volume (m³).

The porosity percentage (ε, %) was calculated through the Mohsenin equation (equation 4):[32]

$$\varepsilon = \left[\left(\rho_t - \rho_b\right)/\rho_t\right] \times 100 \qquad (4)$$

Static friction coefficient: A ramp with an adjustable slope was applied to determine the static friction coefficient. A fiberglass box with the dimensions of 4*10*15cm³ was placed on the frictional surface and filled with the seeds. The applied surfaces were made of multi-layered rubber, plywood and galvanized iron sheet. First, the box was lifted a little from the respective surface to prevent any contact between the box and the surface. The frictional surface is a part of the apparatus which has a joint at one end so that the non-hinge end could be lifted gently using a bolts and nuts system and consequently, the slide angle (α) was considered as the friction angle. Finally, the static friction coefficient was calculated using equation (5):[32]

$$ì_s = tan\acute{a} \qquad (5)$$

Chemical properties

The chemical composition (moisture, ash and fat) of sumac was determined according to AOAC (A.O.A.C., 1990). The protein content was measured through the Kjeldal method.[44]

Extract preparation: The aqueous and ethanolic extracts of epicarp and seed were prepared using distilled water and ethanol 96% through percolation. The extraction procedure was as follows:

The ethanolic extract was obtained after 24h of immersing 10g of the epicarp powder or the sumac seed in 100ml of ethanol 95% at ambient temperature.[45] The aqueous extract was acquired after 1h of immersing 10g of the epicarp powder or the sumac seed in 100ml of distilled water at ambient temperature.[46] The obtained extracts were separated from the solid matter by centrifugation and concentrated using a rotary evaporator and dried at 40°C with a drier. The dry powders resulted from the samples were stored at -18°C until use.

The measurement of the total phenol content, total anthocyanin content, reducing power and free radical scavenging were carried out on the extracts mixture.

The extraction efficiency (w/w) was calculated using the following equation:

$$Efficiency\left(\%\right) = \frac{A}{B} \times 100 \qquad (6)$$

where A represents the weight of the aqueous or the ethanolic extract and B stands for the weight of the epicarp or seed.

Determination of the total phenol content of the extracts: The total phenol content of the extracts was measured through the Folin-Ciocalteu micro-method.[47] 20μl of the reaction solution was mixed with 1.16ml of distilled water and 100μl of Folin- Ciocalteu reagent. After 1-8min, 300μl of Na_2CO_3 solution (20%) was added to the above solution. The obtained mixture was kept at 40°C for 30min

and the absorbance values of the samples were measured at 760nm. The total phenol content of the extracts was expressed as Gallic acid equivalent considering the equation of the standard curve.

Determination of the total anthocyanin content of the extracts: The anthocyanin absorbance values of the extracts were measured at 510 and 700nm at pH=1 and pH=4.5 using a UV-120-02 spectrophotometer (Shimadzu, Japan) and the anthocyanin concentration of the extracts was calculated as mg cyaniding-3-glycoside/kg dried extract via the differential pH method.[48]

$$A = \left(A_{510} - A_{700}\right)_{pH1.0} - \left(A_{510} - A_{700}\right)_{pH4.5} \quad (7)$$

DPPH free radical scavenging assay: The free radical scavenging ability of the extracts was performed based on Hatano et al.[49] Various concentrations (10-50μg/ml) of the extracts were prepared. 0.3ml of each mixture was added to 2.7ml of the methanolic solution containing DPPH (0.02g/l). The samples were kept in darkness at ambient temperature for 30min. the absorbance values of the samples were measured at 517nm and the radical scavenging percentage was calculated using the following equation:

$$Free\ radical\ scavenging\left(\%\right) = \left(\left(absorbance\ value\ of\ the\ sample - absorbance\ value\ of\ the\ blank\ sample\right) / absorbance\ value\ of\ the\ blank\ sample\right)*100$$

(8)

Reducing power: This test was conducted to examine the power of the extracts in reducing Fe (III).[47] 1ml of the sample solution (10-50μg/ml) was mixed with 2.5ml of the phosphate buffer (0.2M, pH=6.6) and 2.5ml of potassium ferricyanide (K_3 Fe $(CN)_6$, 10gl[-1]) and heated at 50°C for 30min. after that, 2.5ml of trichloroacetic acid (100gl[-1]) was added and the mixture was centrifuged for 10min. Eventually, 2.5ml of the supernatant was blended 2.5ml of distilled water and 0.5ml of $FeCl_3$ (1gl[-1]) and the absorbance values of the samples were read at 700nm. The IC_{50} extract concentration was obtained from the curve of the absorbance values at 700nm against the extracts concentration. BHT (a synthetic antioxidant) was used as the blank sample.

Results and discussion

The physical properties of the sumac seed

The physical properties of the sumac fruits harvested from Iran are shown in Table 1. In most cases, the reported values were nearly similar to each other and to those reported for the Turkish sumac fruit.

The m_{1000} of this sumac ranged from 15.9 to 16.9mg. This range was less than that obtained for the Turkish sumac. The bulk density and porosity were in the range of 304.6-306.7kg/m³ and 68.31-97.26%. The average bulk density and porosity were more than those reported for the Turkish sumac.

The range of the static friction coefficient was determined as 0.67-0.69 for rubber, 0.60-0.63 for plywood and 0.48-0.51 for galvanized iron sheet. The mean static friction coefficient of rubber and plywood was higher and these two surfaces are inappropriate for transfer. The lowest coefficient pertained to the galvanized iron sheet. The friction coefficient of agricultural products generally depend on the properties of the foodstuff, moisture content, surface properties, slide speed and the surface material on which the food product moves.[50] Under the same conditions, the surface properties of the seed are the major factor in terms of the slide speed, surface material and the moisture content.

These properties cause the difference between the friction coefficients of various seeds.

Chemical properties of the sumac seed

The approximate contents of the chemical components of sumac fruits are summarized in Table 2. The results indicated that the different compounds of different ecotypes of sumac (Rhus coriaria) were similar. However, these results were a little different from those of Özcan M et al.[25] for the Turkish sumac and Kossah et al.[51] for the Syrian one. The pH of the Syrian sumac has been reported to be equal to 3.7[50] while the pH of this sumac varied from 2.68 to 2.76.

Determination of the total phenol content, total anthocyanin content and extraction efficiency: Tables 3 present the values of the extraction efficiency as well as the total anthocyanin content and total phenol content of the aqueous and ethanolic extracts of different ecotypes of the Khorasan sumac. The results revealed that the solvent type affected the extraction efficiency and the total phenol content of each of the extracts. The total phenol content extracted from sumac with ethanol 96% and water were 10.17 and 4.78 (g Gallic acid/kg dried extract), respectively. The ethanolic extract had the highest extraction efficiency and total phenol content. It seems that the extraction efficiency of the phenolic compounds decreased with the rise in the solvent polarity. In general, the hydrophilic and hydrophobic properties of phytochemical compounds have a considerable effect on their solubility in the applied solvent. Hence, the solvent polarity could have an important role in the extraction efficiency of these compounds.[52]

By creating a completely polar medium, water dissolves a low amount of low-polar phenolic compounds. Furthermore, the aqueous extract contains large amounts of impurities such as organic acids, proteins and soluble sugars, which can interfere in distinguishing and measuring the total phenol content.[53]

Moreover, numerous factors influence the total phenol content of plant tissues, including the genetic factors, extent of sunlight, soil conditions, degree of maturing upon harvest, environmental conditions, climate, post-harvest processing and storage conditions[54]).

As shown in Table 3, the total anthocyanin content of the ethanolic and aqueous extract was equal to 198.12 and 128.19mg/kg extract, demonstrating the total anthocyanin content of the ethanolic extract was higher than that of the aqueous one.

Many studies have reported the direct correlation between the total phenol content and antioxidant activity; nevertheless, Mata AT et al.,[55] found out that the antioxidant activity of plant extracts is not correlated with their high content of phenolic compounds. The solubility of a large number of compounds may be high in a solvent; nonetheless, some of them have a low antioxidant activity or are inactive in this respect.[56]

It has been observed in the studies of former researchers that all parts of sumac, including its fruit, contain noticeable amounts of tannins (glutannin). In a study which has taken a general look at the components present in sumac fruit, the anthocyanins and lipids has been distinguished as the principle components of sumac fruit.[57] Myrtillin, Delphidin and Chrysanthemin have been distinguished as the main anthocyanins of sumac fruit.[58]

Table 1 Biophysical properties of the Iran sumac

Region	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (mm)	Weight of m_{1000} (g)	Volume (mm³)	Sphericity (-)	Bulk density (kg/m³)	Porosity (%)	Coefficient of static friction			Reference
										Rubber	Plywood	Galvanized iron sheet	
Gonabad*	4.98	4.54	2.51	3.84	16.3	22.46	0.76	306.7	68.31	0.68	0.61	0.49	This study
Ferdows*	4.83	4.08	2.33	3.58	16.9	17.64	0.73	304.6	97.26	0.69	0.63	0.51	This study
Zoshk*	4.73	4.21	2.36	3.6	15.9	18.44	0.75	305.4	91.16	0.67	0.6	0.48	This study
Turkey	4.72	3.9	2.64	3.64	18	19.49	0.77	304.25	68.52	0.675	0.607	0.482	Özcan M et al.[25]

*Gonabad, Ferdows and Zoshk are regions of Iran.

Table 2 The compounds of sumac

Reference	pH	Ash (%)	Protein (%)	Fat (%)	Moisture (%)	Regions
This study	2.68	2.0±0.2	2.6±0.1	7.1±0.3	9.6±0.4	Gonabad*
This study	2.76	1.8±0.2	2.4±0.1	7.2±0.4	10.2±0.5	Ferdows*
This study	2.71	1.8±0.2	2.3±0.1	7.0±0.4	9.9±0.5	Zoshk*
Kossah et al.[51]	-	2.66±0.33	2.47±0.12	7.51±0.44	11.8±0.53	Syrian
Kossah et al.[51]	-	6.64±0.03	11.56±0.66	4.31±0.27	5.37±0.14	Turkey
Özcan M et al.[25]	3.7	1.8±0.4	2.6±0.2	7.4±1.6	10.6±1.1	Turkey

*Gonabad, Ferdows and Zoshk are regions of Iran.

Table 3 The separation performance of the whole seed, epicarp and extract (w/w) of the sumac of different regions

Region	Extraction efficiency (%)				Epicarp efficiency (%)	Fruit efficiency (%)	Reference
	Seed		Epicarp				
	Ethanolic	Aqueous	Ethanolic	Aqueous			
Gonabad*	3.57±0.5	3.65±0.4	55.80±2.9	63.45±2.1	59.28±3.1	92.8±1.1	This study
Ferdows*	3.59±0.4	3.68±0.6	56.96±2.5	65.20±3.4	56.17±2.8	94.1±2.3	This study
Zoshk*	3.52±0.5	3.62±0.3	52.24±1.8	62.54±2.7	54.87±2.3	91.9±1.6	This study
Syrian	-	-	55.23	-	-	-	Kossah et al.[51]
Turkey	-	-	63.8±4.2	-	-	-	Özcan M et al.[25]

*Gonabad, Ferdows and Zoshk are regions of Iran.

Assessment of the antioxidant activity

DPPH free radical scavenging assay: Scavenging free radicals is one of the most known mechanisms through which antioxidant compounds could prevent lipids oxidation. In this assay, the scavenging of DPPH is followed by monitoring the decrease in absorbance, which occurs due to the reduction by the antioxidant.[59] The results of the free radical scavenging activity of the aqueous and ethanolic extracts are illustrated in Figure1. As observed, as the extract concentration increased, the extent of free radicals scavenging increased, too. The ethanolic extract showed a higher anti-radical activity at all concentrations.

Overall, the rise in the total phenolic content causes the ability of different extract in free radical scavenging to increase. At higher concentrations of phenolic compounds, the probability of hydrogen donation to free radicals and subsequently the scavenging ability of the extract increases because of the increase in the number of the hydroxyl groups present in the reaction medium.[60] Scavenging of various extracts depends greatly on the number and position of hydroxyl groups and the molecular weight of phenolic compounds. The hydroxyl groups are more easily accessible in lower-molecular-weight phenolic compounds. In addition, phenolic compounds change into phenoxyl free radicals after donating their hydrogen. The stability of these radicals can influence the antioxidant capacity of phenolic compounds, as the less stable phenoxyl radicals compete with DPPH radicals in donating the hydrogen atoms and thus, the scavenging percentage of DPPH free radicals is reduced.[61]

Reducing power: Extraction of antioxidant compounds from plant materials can be conducted through various techniques with different solvents, due to the difference in the chemical nature of these compounds and their unique distribution in the plant tissue.[62] Application of organic and aqueous solvents is the most common

method to extract antioxidant compounds from plant tissues. The extracts with electron-donating activity, can end the radical chain and change the active free radicals into more stable products.[63]

Owing to their reducing power, antioxidant compounds reduce Fe (III) to Fe (II). This reduction could be determined through measuring the formation of blue color at 700nm.[64] In this method, the soluble yellow color of the sample changes into green or blue, depending on the antioxidant or reducing power of the sample. A higher absorbance value displays a higher iron-reducing power.

$$K_3Fe(CN)_6 + Reductive\,agent = Fe(CN)_6^{-4}$$
$$Fe(CN)_6^{-4} + Fecl_3 \rightarrow Fe_4\left[Fe(CN)_6\right]_3 \qquad (9)$$
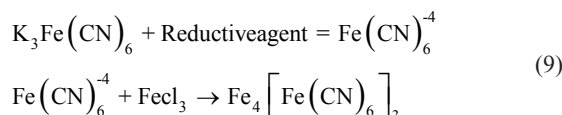
As observed in Figure 2, the iron-reducing activity increased as the sumac and BHT concentration increased. According the results of the present study, the ethanolic extract had a slightly better inhibitory effect compared with BHT; however, the aqueous one was approximately the same as BHT. Furthermore, the iron-reducing power and the total phenol content of the ethanolic extract were higher than those of the aqueous one. The total phenol content and the iron-reducing power are associated with each other. Reduction of Fe (III) is often used as an index for electron donating activity, which is the important mechanism for the evaluation of the antioxidant activity of phenolic compounds.[65]

Figure 1 The percentage of DPPH free radical scavenging by BHT and the aqueous and ethanolic extracts of Iran sumac.
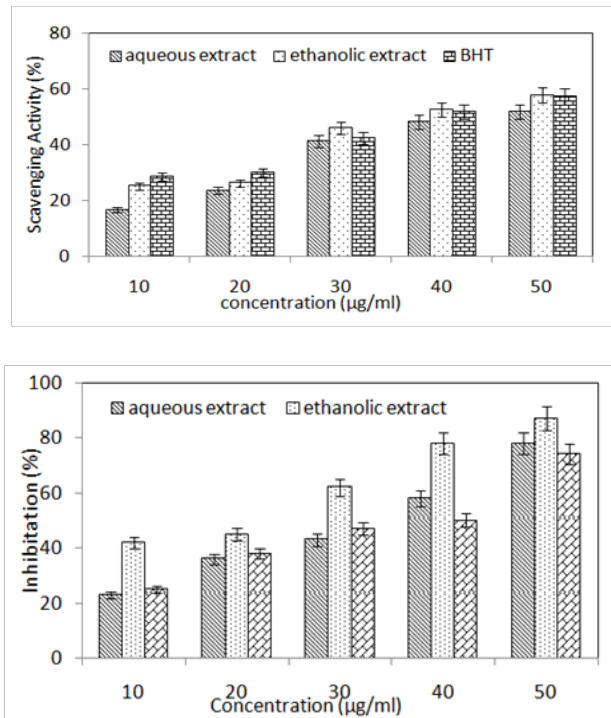

Figure 2 The reducing power of BHT and the aqueous and ethanolic extracts of Iran sumac.

Conclusion

Some of the physical and chemical properties of the sumac fruits of Iran as well as the antioxidant properties of its aqueous and ethanolic extracts were studied. In this study, some engineering properties of sumac fruit were measured. The average m_{1000}, bulk density and porosity percentage ranged from 15.9-16.9g, 304.6-306.7kg/m^3 and 68.31-97.26%, respectively. The galvanized sheet with the lowest static friction coefficient was the best surface for the fruit transfer. The mean length, width, thickness and volume were in the range of 4.73-4.98mm, 4.08-4.54mm, 2.33-2.51mm and 17.64-22.46mm^3, respectively and the mean sphericity coefficient varied from 0.73 to 0.76. This information is of great importance for the design of the equipment of harvest, transfer and processing of sumac fruit. The present study also exhibited that the antioxidant capacity, free radical scavenging and reducing capacity of the ethanolic extract were higher than those of the aqueous one. Moreover, the ethanolic extract had a larger total phenol and anthocyanin content as compared to the aqueous one.

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Conflict of interest

The author declares no conflict of interest.

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