Physical Properties and Chemical Composition of *Pistacia atlantica* subsp. *kurdica* (Zohary) Rech. F. gum: Effect of Geographical Region and Tree Gender

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Summary

Pistacia atlantica subsp. *kurdica* (PAK) is one of three species in Iran and is indigenous to Kurdistan province. The aim of this reaserch was survey of the chemical composition and physical properties of oleoresin gum extracted from different gender of trees in six regions of Kurdistan province (Armardeh, Kanisoor, Marivan, Dezli, Hawraman and Sarvabad). principal component analysis (PCA) assisted in analyzing the dependence of geographical regions and tree gender with the variations of chemical components of gum. Significant differences ($P < 0.05$) were observed in the surface tension, interfacial tension and intrinsic viscosity contents according to gender and geographic region. Spearman rank correlation coefficient results showed significantly positive and negative correlations between gum chemical components and physical characteristics. According to the obtained results and also various medical, cosmetic and food applications of oleoresin, when collecting, the separating extracted oleoresins from trees different regions and genera is necessary.

Key words

baneh, chemical compounds, Kurdistan, physical properties, oleoresin

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Introduction

Pistacia atlantica Desf. or is one of the medicinal plants that covers a very wide geographical area of the world, from the Canary and Atlas Mountains in the west to the mountains of Afghanistan and Iran in the east (Martins et al., 2012). It is a dicotyledonous, perennial plant from *Anacardiaceae* family (Prud'Homme and Long, 1983). Iran is one of the two main centers of Pistacia diversity and is the main producer of pistachios in the world (Babu et al., 2009). *Pistacia atlantica* Desf. subsp. *kurdica* (Zohary) Rech. F. or Baneh is known as green pearl due to its value and various uses among Iranians (Fatahi, 1995).

Oleoresin is the leachate of Baneh tree, which is a semi-concentrated, sticky, smooth green or yellowish-green gum. It is commonly used as a digestive, blood thinner, toothache reliever and tonic compound. The harvesting of oleoresin starts after the spring rains and in the middle of June and lasts for about 1.5 to 2 months (Tabatabai and Ghasriani, 2015). Oleoresin consists of two volatile parts (turpentine) and non-volatile (clofan) (Fatahi, 1995). Turpentine is the volatile essential oil of oleoresin, which has a pungent odor and a bitter taste. Clofan is a non-volatile yellowish-white substance that remains after the evaporation of turpentine and is traditionally used as chewing gum (Heidari, 1995). Oleoresin essential oil contains large amounts of monoterpene compounds, of which alpha pinene is the predominant compound (Sharifi and Hazell, 2011).

Researches has shown that the compounds of Baneh gum have anti-Helicobacter pylori activity and play in the treatment of gastric ulcers (Vandenabeele et al., 2000). In addition, its antimicrobial and bacterial properties have been reported on a wide range of bacteria (Sharifi et al., 2012). In vitro reports indicate that oleoresin inhibits the proliferation and cause death of cancer cells (HCT116) in the human colon (Hosseini et al., 2013).

The antioxidant activity and chemical composition of essential oil of Atlantica Baneh species in Algeria were evaluated. The radical scavenging capacity by DPPH method was estimated 8.8-28.8 mg ml^{-1} (N Gourine et al., 2010). The antibacterial properties of Baneh essential oil on *Staphylococcus aureus*, *Escherichia coli* and *Clostridium perfringens* were evaluated. According to the results, *Staphylococcus aureus* showed the highest sensitivity and *Clostridium sporogenesis* showed the highest resistance to essential oil (Hanafi et al., 2012).

Several studies have been performed on the chemical composition of essential oil and gum of *Pistacia atlantica* subsp. *kurdica* (PAK) in different regions of the world (Barrero et al., 2005; Farhoosh et al., 2008; Mirahmadi et al., 2019).

Thermal properties (thermal stability, heat capacity, energy of activation and glass transition temperature) were determined for PAK gums in different regions in Kurdistan province in western Iran (Mirahmadi et al., 2019).

Most plant gums have a heteropolysaccharide structure. The functional properties of gums are affected by the molecular structure and chemical composition (Ibrahim et al., 2013). The critical concentration and intrinsic viscosity of biopolymers play a pivotal role in their rheological behavior. Behrouzian et al. (2014) describe the capability of a specific biopolymer to increase solution viscosity.

Some work has been done to study the surface and interfacial properties of natural hydrocolloids (Dickinson et al., 1988). Both classes of proteins and polysaccharide biopolymers are related to the structural and textural properties of foods through their aggregation and gelatin behavior. Food biopolymers have very different functional properties depending on chemical composition, molecular weight, particle size distribution, and solution conditions such as pH, ionic strength, and specific ions (Dickinson et al., 1988; Rashidi et al., 2010). Several studies have been done to study the surface activity of a group of acacia gums. They showed some correlation between protein content and long-time interfacial tension (Castellani et al., 2008; Dickinson et al., 1988)

The aim of this study was to investigate the chemical composition and physical properties of oleoresin gum of *P. atlantica* subsp. *kurdica* in the forests of Kurdistan, Iran.

Materials and methods

Sampling

The Baneh trees were identified in regions in Kurdistan province and divided into hypothetical populations according to climate and geographical distances. The selected trees were numbered at the place of growth and all its geographical characteristics were recorded using GPS and sampling points were drawn (Fig. 1). The species identification was performed using herbarium of Kurdistan University.

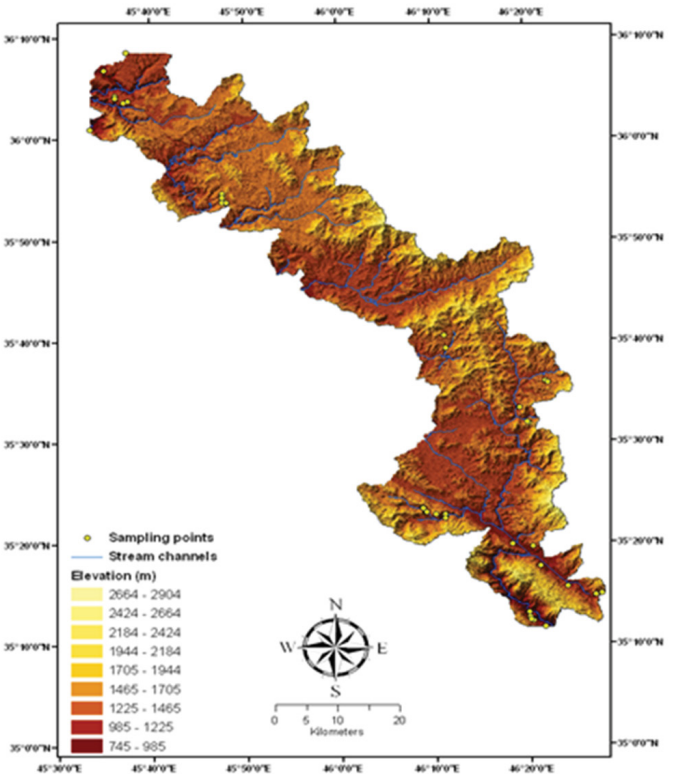

Figure 1. Map of studied regions of Pistacia atlantica subsp. kurdica in Kurdistan province

Oleoresin Extraction

After the spring rains in late June to early July, oleoresin was extracted from the trunks of the studied trees. The trunks of the trees were first wounded with an ax so that the bark was completely removed at the cutting site. After axing, clay jars were placed under each wound and scratch to collect the seepage of oleoresin. Usually after about 20 days, re-wounding was done in order to further extraction of oleoresin.

Experiments

Chemical properties

The moisture content was determined based on the percentage of weight loss in before and after dehydration. The ash content was measured according to AOAC method (1990). Protein content was determined by Kjeldahl method (Mirhosseini et al., 2013).

Determination of total sugar

Total sugar was determined based on the Phenol-sulfuric acid method. First, different concentrations of glucose were prepared and analyzed with samples of 4% sugar solution. 1 mL of standard samples and solutions were added separately to 1 mL of 5% phenol solution and mixed. Then 5 mL of concentrated sulfuric acid was added and vortex for 30 seconds. It was kept at 25 °C for 20 minutes and then the absorbance was read by a spectrophotometer at 490 nm (Broido, 1969).

Monosaccharide Measurement

30 µl of sodium hydroxid and 20 µL of phenyl 3 methyl 5 pyrazolone was added to oleoresin gum. Then, fucose sugar was added as an internal standard to each specimen before derivatization. The mixture was incubated at 70 °C for 60 minutes, then cooled to room temperature and neutralized with 30 µL of hydrochloric acid. Then 1 mL of trichloromethane was added and stirred vigorously, then the top layer was removed. The organic layer was carefully separated and after filtering, it was injected into the HPLC (Unicam-crystal-200, England) (column 0.45 mm) (Ai et al., 2016).

Amino acid analysis

5 ml hydrochloric acid was added to each sample gums and incubated at 11 °C for 18 hours. The hydrolyzed liquid was neutralized with bicarbonate for 10 hours. Centrifuge at 13,500 g per minute. The zinc liquid was separated and 200 µL was removed and mixed separately with 50 µL 4-4 dimethyl aminophenyl azo-benzene sulfonyl chloride to convert the amino acids to dextyl chloride compounds and incubated for 1 hour at 60 °C. The acetone in the solution required for the decylation of chloride was evaporated and used for HPLC injection (Krause et al., 1995).

Volatile compound analysis

The gum samples were dissolved in 90% ethanol solution and mixed with sodium hydroxide for the soap making process and then boiled for 2 minutes. After cooling, the saturated NaCl solution was added to the samples. The solutions were then poured into a separating funnel and 30 ml of petroleum ether was added and converted to methyl ester by 20 mL of boron methanol trifluoride reagent. Finally, the volatile compounds were determined by Gas Chromatography-Mass Spectrometry (Agilent 6890N, USA) (Orhan et al., 2007).

Physical properties

Surface tension

The surface tension of pure liquid gum samples was measured by tensiometer (model k100, KRÜSS company, Germany) and by double ring method at 23 °C and relative humidity of 45%. The sunflower oil was used as standard Interfacial solution (McClements, 2015).

Intrinsic viscosity

The intrinsic viscosity of gum samples was determine by Viscometer (Ubbelhode Cappillary, 52520 / II, Schott, Germany), where concentrations of 2, 1 and 3 g / l were prepared, and then the viscosity was determined based on these concentrations (López-Franco et al., 2013).

Statistical Analysis

The statistical analysis was accomplished using a two-way general liner model design analysis of variance (ANOVA) with the factors of geographic region and gender (SAS9.3) and Tukey's HSD test at $P < 0.05$ significance level for separation of mean values. Non-parametric Spearman rank correlation coefficients of chemical and physical properties was determined using the SPSS software (v. 22).

Results and discussion

Environmental analysis

The results of geographic information system (GIS) analysis for all sampling regions (are summarized in the Table 1. Significant differences were observed in all characteristics ($P < 0.01$) contents for geographic region, but no significant difference for gender was found.

Principal Component Analysis (PCA)

In order to the scrutinizing inunderstanding we have used of PCA algorithm that can reduce the data dimentions into 2-dimensional space and enable better understanding of the complex data shown in Tables 2, 3 and 4.

In different types of gums, the values of monosaccharides, amino acids and volatile compounds were expected highly dependent on the geographic regions and gender. The active variables with Chounlamany et al. (2017) categorized the factor loading values as follows:

(i) Factor loading value > 0.75 as "strong",

(ii) 0.50 < Factor loading value < 0.75 as "moderate", and

(iii) 0.50 < Factor loading value < 0.30 as "weak".

According on monosaccharides, amino acids and volatile compounds analysis through two PCs and also similarities through the cluster analysis (Fig. 2), four region groups may be determined, identified by ellipse areas on the two-dimensional PCA plot (Fig. 3).

Table 1. Environmental characteristics of sampling regions based on Geographic Information System (GIS) analysis

Sample	Gender		Geographic regions					
	Female	Male	Kanisoor	Armardeh	Hawraman	Dezli	Sarvabad	Marivan
SI (MW m^{-2})	1.43 ± 0.11 ^{a}	1.47 ± 0.09 ^{a}	1.55 ± 0.05 ^{a}	1.56 ± 0.08 ^{a}	1.30 ± 0.09 ^{a}	1.47 ± 0.13 ^{a}	1.48 ± 0.10 ^{a}	1.33 ± 0.11 ^{a}
EI (m)	1436.60 ± 113.35 ^{a}	1393.70 ± 46.45 ^{a}	1394.20 ± 72.20 ^{bc}	1676.20 ± 27.80 ^{a}	1087.50 ± 51.85 ^{d}	1457.70 ± 56.50 ^{bc}	1325.30 ± 21.45 ^{c}	1550.20 ± 50.53 ^{ab}
DS(m)	1344 ± 548 ^{a}	1035 ± 405 ^{a}	1913 ± 812 ^{a}	2143 ± 131 ^{a}	839 ± 163 ^{b}	272.1 ± 110.1 ^{ab}	1187 ± 281 ^{ab}	785 ± 235 ^{ab}
MAT (°C)	11.89 ± .49 ^{a}	12.05 ± 0.48 ^{a}	13.01 ± 0.14 ^{b}	11.01 ± 0.02 e	13.26 ± 0.02 ^{a}	10.89 ± 0.07 ^{f}	12.26 ± 0.03 ^{c}	11.39 ± 0.05 ^{d}
TAP (mm)	773.88 ± 17.37 ^{a}	773.74 ± 18.08 ^{a}	743.76 ± 0.82 ^{f}	771.39 ± 0.34 ^{b}	766.26 ± 0.03 c	847.51 ± 0.52 ^{a}	753.82 ± 5.17 ^{e}	760.14 ± 3.72 ^{d}
SLO (%)	39.56 ± 12.82 ^{a}	35.78 ± 9.61 ^{a}	21.17 ± 4.02 ^{a}	34.83 ± 4.09 ^{a}	32.70 ± 12.75 ^{a}	50.50 ± 15.95 ^{a}	49.83 ± 11.38 ^{a}	37.00 ± 10.72 ^{a}

Note: DS: Distance from the stream channel (m); SI: Solar illumination during one year (MW m^{-2}); EI: Elevation (m); MAT: Mean annual temperature (°C); TAP: Total annual precipitation (mm); SLO: Slope (%); Values with different letters in each row are significantly different according to Tukey's HSD test at $P < 0.05$ significance level

Table 2. Chemical composition of the extracted gum samples for factors under investigation

Sample	Gender		Geographic regions					
	Female	Male	Kanisoor	Armardeh	Hawraman	Dezli	Sarvabad	Marivan
Total Portein (%)	4.63 ± 0.22 ^{a}	4.23 ± 0.20 ^{b}	4.09 ± 0.12 ^{d}	4.82 ± 0.15 ^{b}	4.18 ± 0.05 ^{d}	4.47 ± 0.15 ^{c}	5.05 ± 0.13 ^{a}	3.97 ± 0.11 ^{e}
Moisture (%)	18.30 ± 1.28 ^{a}	18.60 ± 1.31 ^{a}	18.81 ± 0.93 ^{a}	18.89 ± 1.35 ^{a}	18.58 ± 0.50 ^{a}	16.03 ± 0.19 ^{a}	19.12 ± 2.20 ^{a}	19.26 ± 0.16 ^{a}
Ash (%)	0. 93 ± 0.002 ^{a}	0. 88 ± 0.003 ^{b}	0. 94 ± 0.002 ^{a}	0. 92 ± 0.003 ^{ab}	0. 86 ± 0.003 ^{b}	0. 91 ± 0.003 ^{ab}	0. 93 ± 0.002 ^{ab}	0. 87 ± 0.002 ^{ab}
Totalcarbohydrates (%)	40.51 ± 2.35 ^{b}	44.74 ± 2.53 ^{a}	45.56 ± 2.12 ^{a}	41.23 ± 3.04 ^{a}	43.36 ± 1.63 ^{a}	44.01 ± 2.63 ^{a}	39.83 ± 1.33 ^{a}	41.76 ± 1.76 ^{a}
Arabinose*	73.63 ± 6.09 ^{a}	66.88 ± 5.32 ^{b}	78.00 ± 4.13 ^{b}	74.00 ± 0.85 ^{c}	60.50 ± 1.51 ^{e}	69.00 ± 0.85 ^{d}	53.50 ± 1.66 ^{f}	86.50 ± 2.20 ^{a}
Galactose	53.42 ± 5.55 ^{a}	49.42 ± 5,66 ^{b}	50.00 ± 2.47 ^{d}	69.00 ± 0.97 ^{a}	36.50 ± 0.69 ^{f}	59.63 ± 0.81 ^{b}	41.38 ± 1.38 ^{e}	52.00 ± 1.38 ^{c}
Rhamnose	20.96 ± 3.18 ^{a}	19.08 ± 2.47 ^{b}	20.33 ± 0.40 ^{c}	13.08 ± 0.48 ^{f}	28.85 ± 1.50 ^{a}	17.63 ± 0.29 ^{d}	24.15 ± 0.93 ^{b}	15.40 ± 0.31 ^{e}
Fucose	3.58 ± 1.45 ^{a}	3.27 ± 1.06 ^{b}	1.73 ± 0.33 ^{d}	1.38 ± 0.01 ^{e}	6.15 ± 0.49 ^{b}	2.37 ± 0.15 ^{c}	7.43 ± 0.32 ^{a}	1.49 ± 0.10 ^{e}
Xylose	24.00 ± 4.98 ^{b}	25.5 ± 4.35 ^{a}	21.50 ± 1.16 ^{c}	17.00 ± 0.38 ^{e}	36.50 ± 0.59 ^{b}	19.00 ± 0.38 ^{d}	38.00 ± 0.85 ^{a}	16.50 ± 0.59 ^{e}
Glucose	5.07 ± 1.05 ^{a}	4.69 ± 1.25 ^{b}	4.63 ± 0.13 ^{c}	2.40 ± 0.19 ^{e}	7.58 ± 0.29 ^{b}	3.35 ± 0.14 ^{d}	8.08 ± 0.35 ^{a}	3.25 ± 0.49 ^{d}
Glucuronic acid	22.88 ± 2.78 ^{a}	17.47 ± 2.77 ^{b}	15.30 ± 0.59 ^{e}	15.70 ± 2.99 ^{e}	23.33 ± 2.03 ^{b}	30.13 ± 1.45 ^{a}	19.60 ± 0.85 ^{c}	16.50 ± 0.23 ^{f}
Galacturonic acid	43.63 ± 5.37 ^{a}	35.33 ± 4.98 ^{b}	34.23 ± 1.69 ^{d}	49.80 ± 2.58 ^{b}	27.80 ± 0.52 ^{e}	28.30 ± 3.18 ^{e}	44.75 ± 4.11 ^{c}	52.00 ± 1.39 ^{a}

Note: * Unit for monosaccharide: mg g^{-1} of carbohydrate; values with different letters in each row are significantly different according to Tukey's HSD test at $P < 0.05$ significance level

Table 3. Chemical composition (Total Portein and Amino acids) of the extracted gum samples for factors under investigation

Sample	Gender		Geographic regions					
	Female	Male	Kanisoor	Armardeh	Hawraman	Dezli	Sarvabad	Marivan
Total Portein (%)	4.63 ± 0.22 ^{a}	4.23 ± 0.20 ^{b}	4.09 ± 0.12 ^{d}	4.82 ± 0.15 ^{b}	4.18 ± 0.05 ^{d}	4.47 ± 0.15 ^{c}	5.05 ± 0.13 ^{a}	3.97 ± 0.11 ^{e}
Alanine*	46.17 ± 5.37 ^{a}	35.33 ± 4.98 ^{b}	50.00 ± 0.35 ^{b}	40.63 ± 7.60 ^{c}	33.88 ± 1.86 ^{e}	53.00 ± 5.76 ^{a}	37.63 ± 2.82 ^{d}	29.38 ± 3.23 ^{f}
Glycine	40.29 ± 5.68 ^{b}	42.38 ± 5.83 ^{a}	37.00 ± 0.43 ^{d}	32.50 ± 0.59 ^{e}	59.00 ± 0.89 ^{a}	25.50 ± 0.53 ^{f}	43.5 ± 0.59 ^{c}	50.50 ± 0.55 ^{b}
Lysine	41.75 ± 1.87 ^{b}	46.33 ± 2.88 ^{a}	43.85 ± 0.43 ^{cd}	47.60 ± 5.75 ^{a}	44.18 ± 1.61 ^{bc}	43.57 ± 1.93 ^{d}	44.30 ± 0.68 ^{b}	40.75 ± 1.45 ^{e}
Cysteine	4.16 ± 0.88 ^{a}	3.42 ± 1.43 ^{b}	2.98 ± 0.52 ^{d}	4.05 ± 0.02 ^{c}	1.60 ± 0.74 ^{e}	5.93 ± 0.56 ^{b}	7.03 ± 0.65 ^{a}	1.15 ± 0.53 ^{f}
Threonine	35.29 ± 4.88 ^{b}	47.39 ± 6.23 ^{a}	50.25 ± 0.21 ^{b}	40.80 ± 8.06 ^{c}	34.13 ± 1.72 ^{e}	55.38 ± 6.51 ^{a}	38.05 ± 3.26 ^{d}	29.45 ± 3.65 ^{f}
Valine	34.02 ± 5.14 ^{a}	31.98 ± 4.98 ^{b}	48.75 ± 0.75 ^{a}	42.00 ± 0.85 ^{b}	33.25 ± 0.44 ^{c}	25.13 ± 0.62 ^{e}	19.90 ± 0.55 ^{f}	29.00 ± 0.35 ^{d}
Phenylalanine	24.71 ± 3.08 ^{a}	17.20 ± 2.24 ^{b}	16.75 ± 2.61 ^{e}	16.50 ± 0.59 ^{e}	23.00 ± 1.93 ^{b}	18.50 ± 1.66 ^{d}	29.47 ± 2.35 ^{a}	21.50 ± 4.39 ^{c}
Histidine	78.67 ± 6.13 ^{b}	85.17 ± 6.18 ^{a}	101.50 ± 2.20 ^{a}	71.00 ± 1.93 ^{e}	91.50 ± 1.12 ^{b}	77.50 ± 1.92 ^{d}	66.50 ± 1.66 ^{f}	83.50 ± 1.95 ^{c}
Glutamine	30.51 ± 3.35 ^{b}	32.63 ± 3.38 ^{a}	36.38 ± 0.71 ^{b}	39.85 ± 0.85 ^{a}	34.08 ± 0.51 ^{c}	28.10 ± 0.61 ^{e}	19.50 ± 0.59 ^{f}	31.50 ± 0.59 ^{d}
Isoleucine	25.98 ± 4.30 ^{a}	24.61 ± 4.31 ^{b}	21.50 ± 0.49 ^{d}	40.00 ± 0.35 ^{a}	18.00 ± 0.85 ^{e}	32.50 ± 0.59 ^{b}	23.25 ± .22 ^{c}	16.50 ± 0.23 ^{f}
Asparagine	47.00 ± 6.47 ^{a}	42.75 ± 6.47 ^{b}	33.50 ± 0.59 ^{e}	36.00 ± 3.57 ^{d}	44.50 ± 1.12 ^{c}	34.00 ± 1.48 ^{e}	53.50 ± 1.11 ^{b}	67.75 ± 1.55 ^{a}
Methionine	17.08 ± 2.22 ^{a}	22.13 ± 6.62 ^{a}	12.63 ± 2.14 ^{a}	11.00 ± 0.35 ^{a}	13.63 ± 0.35 ^{a}	20.25 ± 0.70 ^{a}	20.13 ± 1.59 ^{a}	15.00 ± 3.02 ^{a}
Serine	106.08 ± 8.13 ^{a}	95.50 ± 6.25 ^{b}	78.00 ± 1.83 ^{f}	115.50 ± 2.75 ^{b}	90.75 ± 2.10 ^{e}	104.50 ± 2.75 ^{c}	118.00 ± 5.76 ^{a}	98.00 ± 2.49 ^{d}
Arginine	23.63 ± 4.29 ^{b}	24.08 ± 5.71 ^{a}	9.75 ± 0.44 ^{f}	29.50 ± 0.59 ^{c}	20.25 ± 1.24 ^{d}	15.50 ± 0.59 ^{f}	33.25 ± 3.72 ^{b}	34.88 ± 0.27 ^{a}
Proline	94.67 ± 6.90 ^{a}	103.42 ± 7.52 ^{a}	118.75 ± 2.90 ^{a}	87.25 ± 2.09 ^{e}	111.25 ± 2.63 ^{b}	94.25 ± 2.34 ^{d}	78.00 ± 1.93 ^{f}	104.75 ± 2.61 ^{c}
Tyrosine	38.75 ± 4.16 ^{a}	27.25 ± 5.16 ^{b}	35.00 ± 3.02 ^{b}	31.25 ± 3.18 ^{d}	33.75 ± 2.34 ^{c}	26.50 ± 2.75 ^{f}	27.25 ± 6.99 ^{e}	46.25 ± 3.70 ^{a}
Glutamic acid	159.50 ± 10.15 ^{b}	184.00 ± 9.42 ^{a}	172.80 ± 13.15 ^{b}	168.75 ± 10.00 ^{b}	181.50 ± 5.50 ^{a}	183.75 ± 11.11 ^{a}	171.50 ± 14.00 ^{b}	152.25 ± 11.91 ^{c}
Aspartic acid	118.42 ± 7.60 ^{b}	103.83 ± 6.53 ^{a}	89.00 ± 3.06 ^{f}	122.25 ± 4.25 ^{b}	98.00 ± 3.57 ^{e}	117.25 ± 4.25 ^{c}	128.75 ± 4.80 ^{a}	111.50 ± 4.13 ^{d}
Leucine	30.42 ± 5.44 ^{a}	29.17 ± 4.82 ^{b}	29.75 ± 5.35 ^{c}	18.00 ± 0.05 ^{f}	28.75 ± 1.28 ^{d}	32.50 ± 3.84 ^{b}	45.25 ± 1.55 ^{a}	24.50 ± 3.30 ^{e}
Tryptophan	7.45 ± 2.25 ^{a}	5.83 ± 2.17 ^{b}	5.50 ± 1.66 ^{d}	2.88 ± 1.58 ^{e}	9.50 ± 1.12 ^{b}	12.50 ± 1.12 ^{a}	1.50 ± 0.82 ^{f}	8.00 ± 0.35 ^{c}

Note: * Unit for amino acids: mg g^{-1} of protein.; Values with different letters in each row are significantly different according to Tukey's HSD test at $P < 0.05$ significance level

Table 4. Volatile components of the extracted gum samples for factors under investigation

Sample	RI	Gender		Geographic regions					
		Female	Male	Kanisoor	Armardeh	Hawraman	Dezli	Sarvabad	Marivan
1,3 Octanal	873	1.15 ± 0.16 ^{a}	0.91 ± 0.25 ^{b}	1.25 ± 0.22 ^{b}	1.36 ± 0.03 ^{a}	1.00 ± 0.16 ^{c}	0.43 ± 0.23 ^{e}	1.25 ± 0.14 ^{b}	0.90 ± 0.08 ^{d}
Tricyclene	898	0.98 ± 0.08 ^{b}	1.06 ± 0.09 ^{a}	1.00 ± 0.04 ^{a}	0.85 ± 0.02 ^{b}	1.00 ± 0.03 ^{a}	1.10 ± 0.03 ^{a}	1.10 ± 0.07 ^{a}	1.08 ± 0.17 ^{a}
α-Thujene	908	1.64 ± 0.16 ^{a}	1.60 ± 0.25 ^{b}	1.70 ± 0.03 ^{b}	1.70 ± 0.19 ^{b}	1.95 ± 0.11 ^{a}	1.35 ± 0.22 ^{c}	1.95 ± 0.13 ^{a}	1.08 ± 0.04 ^{d}
α-Pinene	920	44.41 ± 2.16 ^{a}	43.39 ± 1.93 ^{b}	40.15 ± 1.07 ^{e}	41.00 ± 1.69 ^{d}	45.05 ± 2.00 ^{b}	44.80 ± 0.14 ^{b}	42.83 ± 1.63 ^{c}	49.58 ± 1.26 ^{a}
Comphene	935	2.63 ± 0.73 ^{b}	3.32 ± 0.93 ^{a}	3.48 ± 0.09 ^{b}	3.10 ± 0.95 ^{b}	3.05 ± 0.82 ^{c}	3.05 ± 0.90 ^{c}	1.43 ± 0.09 ^{c}	3.83 ± 1.51 ^{a}
verbenone	946	1.20 ± 0.17 ^{b}	0.88 ± 0.35 ^{a}	0.50 ± 0.27 ^{e}	0.96 ± 0.05 ^{c}	1.20 ± 0.05 ^{b}	1.78 ± 0.07 ^{a}	0.78 ± 0.43 ^{c}	1.00 ± 0.04 ^{c}
sabinene	960	1.53 ± 0.22 ^{a}	1.35 ± 0.21 ^{b}	1.20 ± 0.19 ^{c}	2.10 ± 0.03 ^{a}	1.18 ± 0.07 ^{c}	1.20 ± 0.18 ^{c}	1.73 ± 0.15 ^{b}	1.25 ± 0.08 ^{c}
β-Pinene	971	4.41 ± 0.42 ^{b}	5.55 ± 0.74 ^{a}	5.20 ± 0.08 ^{c}	6.10 ± 0.74 ^{a}	4.65 ± 0.05 ^{d}	4.65 ± 0.08 ^{d}	5.55 ± 0.65 ^{b}	3.73 ± 0.55 ^{e}
Myrcene	990	1.57 ± 0.18 ^{a}	1.58 ± 0.25 ^{a}	1.75 ± 0.18 ^{ab}	1.30 ± 0.19 ^{d}	1.83 ± 0.21 ^{a}	1.63 ± 0.14 ^{bc}	1.48 ± 0.24 ^{c}	1.48 ± 0.28 ^{c}
3-carene	1006	3.40 ± 0.63 ^{a}	1.89 ± 0.82 ^{b}	1.98 ± 0.53 ^{cd}	1.93 ± 1.06 ^{d}	2.53 ± 1.38 ^{bc}	2.68 ± 0.48 ^{b}	4.45 ± 0.04 ^{a}	2.33 ± 0.15 ^{bcd}
α-Phelandrene	1020	1.50 ± 0.19 ^{b}	1.71 ± 0.29 ^{a}	2.23 ± 0.15 ^{a}	1.68 ± 0.16 ^{c}	0.95 ± 0.02 ^{e}	1.28 ± 0.12 ^{d}	1.85 ± 0.08 ^{b}	1.65 ± 0.25 ^{c}
β-Ocimene	1031	1.49 ± 0.23 ^{a}	1.13 ± 0.13 ^{b}	1.45 ± 0.22 ^{b}	1.04 ± 0.08 ^{d}	1.48 ± 0.32 ^{b}	1.28 ± 0.15 ^{c}	1.63 ± 0.14 ^{a}	1.00 ± 0.02 ^{d}
p-cymen	1040	1.41 ± 0.17 ^{b}	1.60 ± 0.26 ^{a}	1.53 ± 0.07 ^{b}	1.03 ± 0.02 ^{e}	1.93 ± 0.26 ^{a}	1.40 ± 0.25 ^{c}	1.25 ± 0.14 ^{d}	1.90 ± 0.08 ^{a}
Fenchone	1052	0.73 ± 0.28 ^{b}	1.35 ± 0.20 ^{a}	0.38 ± 0.20 ^{e}	1.18 ± 0.13 ^{bc}	1.08 ± 0.02 ^{cd}	1.20 ± 0.16 ^{b}	1.00 ± 0.55 ^{d}	1.43 ± 0.04 ^{a}
Limonene	1065	2.85 ± 0.47 ^{b}	3.96 ± 0.84 ^{a}	3.30 ± 0.41 ^{d}	4.65 ± 0.80 ^{a}	3.30 ± 0.14 ^{d}	3.80 ± 0.08 ^{c}	4.40 ± 0.52 ^{b}	0.98 ± 0.02 ^{e}
1,8-cineole	1084	1.08 ± 0.09 ^{b}	1.66 ± 0.23 ^{a}	1.53 ± 0.26 ^{b}	1.00 ± 0.08 ^{d}	1.54 ± 0.32 ^{b}	1.45 ± 0.08 ^{c}	0.99 ± 0.01 ^{d}	1.72 ± 0.21 ^{a}
γ- terpinene	1105	1.53 ± 0.23 ^{a}	1.21 ± 0.13 ^{b}	1.00 ± 0.04 ^{c}	1.75 ± 0.16 ^{a}	1.44 ± 0.06 ^{b}	1.70 ± 0.19 ^{a}	1.36 ± 0.23 ^{b}	0.98 ± 0.02 ^{c}
α-terpinolene	1122	2.73 ± 0.71 ^{b}	3.01 ± 0.55 ^{a}	2.13 ± 0.02 ^{c}	4.81 ± 0.04 ^{a}	2.00 ± 0.33 ^{c}	3.20 ± 0.65 ^{b}	1.84 ± 0.26 ^{d}	3.24 ± 0.54 ^{b}
Citronellal	1140	1.32 ± 0.38 ^{b}	1.35 ± 0.23 ^{a}	1.95 ± 0.06 ^{a}	1.63 ± 0.37 ^{b}	1.40 ± 0.19 ^{c}	1.35 ± 0.16 ^{c}	0.90 ± 0.04 ^{d}	0.78 ± 0.43 ^{e}
Linalool	1162	1.43 ± 0.23 ^{a}	1.35 ± 0.24 ^{b}	1.60 ± 0.07 ^{b}	1.00 ± 0.08 ^{e}	1.25 ± 0.20 ^{c}	2.20 ± 0.04 ^{a}	1.14 ± 0.02 ^{d}	1.15 ± 0.16 ^{cd}
Cis-verbenol	1180	0.80 ± 0.34 ^{b}	0.89 ± 0.24 ^{a}	1.00 ± 0.04 ^{c}	0.75 ± 0.41 ^{d}	0.48 ± 0.26 ^{e}	0.38 ± 0.20 ^{f}	1.30 ± 0.33 ^{a}	1.18 ± 0.05 ^{b}
Trans-pinocarveol	1196	1.03 ± 0.23 ^{b}	1.18 ± 0.14 ^{a}	1.58 ± 0.05 ^{a}	0.93 ± 0.10 ^{d}	1.08 ± 0.14 ^{c}	1.13 ± 0.11 ^{c}	0.50 ± 0.29 ^{e}	1.40 ± 0.14 ^{b}
trans-verbenol	1212	4.95 ± 0.61 ^{b}	5.13 ± 0.70 ^{a}	5.85 ± 0.86 ^{a}	5.93 ± 0.56 ^{a}	4.15 ± 0.30 ^{c}	4.63 ± 0.37 ^{b}	5.73 ± 0.57 ^{a}	3.95 ± 0.05 ^{c}

Continued. Table 4

Sample	RI	Gender		Geographic regions					
		Female	Male	Kanisoor	Armardeh	Hawraman	Dezli	Sarvabad	Marivan
Terpinen-4-ol	1240	1.17 ± 0.11 [a]	1.03 ± 0.26 [b]	1.13 ± 0.10 [b]	1.55 ± 0.07 [a]	1.13 ± 0.05 [b]	1.15 ± 0.11 [b]	1.18 ± 0.07 [b]	0.48 ± 0.26 [c]
myrtenal	1264	1.08 ± 0.11 [b]	1.23 ± 0.12 [a]	1.50 ± 0.08 [a]	0.93 ± 0.05 [d]	1.15 ± 0.11 [b]	1.13 ± 0.14 [bc]	1.13 ± 0.07 [bc]	1.08 ± 0.02 [c]
myrtenol	1277	1.11 ± 0.14 [a]	0.84 ± 0.22 [b]	1.11 ± 0.19 [b]	1.34 ± 0.06 [a]	0.83 ± 0.01 [d]	1.04 ± 0.05 [c]	0.66 ± 0.36 [d]	0.88 ± 0.08 [d]
Trans-carveol	1297	0.92 ± 0.23 [b]	1.25 ± 0.19 [a]	1.20 ± 0.08 [b]	1.10 ± 0.08 [c]	1.23 ± 0.05 [b]	0.53 ± 0.23 [e]	0.84 ± 0.02 [d]	1.63 ± 0.19 [a]
Bornyl acetate	1339	1.15 ± 0.12 [a]	0.71 ± 0.26 [b]	1.20 ± 0.08 [a]	1.06 ± 0.06 [b]	1.25 ± 0.17 [a]	0.48 ± 0.26 [d]	1.04 ± 0.05 [b]	0.56 ± 0.30 [c]
p-cymen-7-ol	1355	0.83 ± 0.21 [b]	0.94 ± 0.21 [a]	0.90 ± 0.02 [c]	0.00 [d]	0.93 ± 0.11 [c]	1.27 ± 0.02 [a]	1.00 ± 0.14 [b]	1.24 ± 0.17 [a]
α-Burbonene	1369	0.94 ± 0.10 [b]	1.13 ± 0.11 [a]	0.85 ± 0.02 [d]	1.05 ± 0.11 [b]	1.14 ± 0.10 [a]	1.19 ± 0.14 [a]	1.04 ± 0.15 [b]	0.95 ± 0.02 [c]
α-terpenyl acetate	1396	1.29 ± 0.12 [a]	1.09 ± 0.12 [b]	1.43 ± 0.04 a	1.29 ± 0.18 [b]	1.18 ± 0.13 [c]	1.05 ± 0.02 [d]	1.14 ± 0.16 [cd]	1.06 ± 0.11 [d]
longifolene	1440	3.91 ± 0.71 [a]	3.23 ± 1.02 [b]	5.30 ± 0.41 [a]	2.35 ± 0.65 [f]	2.70 ± 0.48 [e]	3.93 ± 0.37 [c]	4.34 ± 0.63 [b]	2.83 ± 1.00 [d]
Germacren D	1505	0.96 ± 0.11 [a]	0.88 ± 0.22 [b]	0.91 ± 0.02 [d]	0.80 ± 0.07 [e]	0.40 ± 0.22 [f]	1.10 ± 0.03 [b]	0.98 ± 0.02 [c]	1.35 ± 0.02 [a]
α-Muurolene	1537	0.64 ± 0.25 [a]	0.61 ± 0.25 [b]	0.38 ± 0.20 [e]	0.92 ± 0.16 [b]	1.01 ± 0.16 [a]	0.49 ± 0.26 [d]	0.36 ± 0.14 [e]	0.58 ± 0.31 [c]
Total Volatile organic compounds (%)		27.88	27.39	26.47	26.73	28.67	27.04	28.28	28.59

Note: Values with different letters in each raw are significantly different according to Tukey's HSD test at $P < 0.05$ significance level

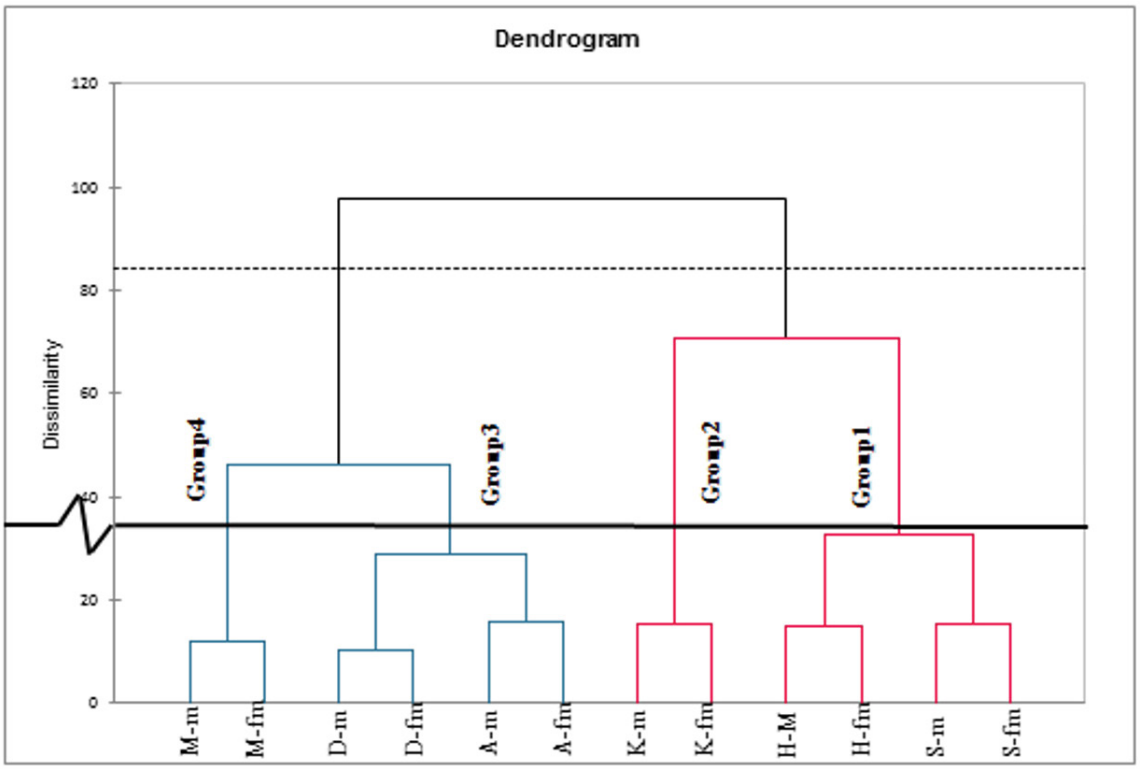

Figure 2. Dentogram representing the cluster of the gum samples of different geographic region and gender. M: Marivan, H: Hawraman, A: Armardeh, K: Kanisoor, D: Dezli, S: Sarvabad, m: male, fm: female

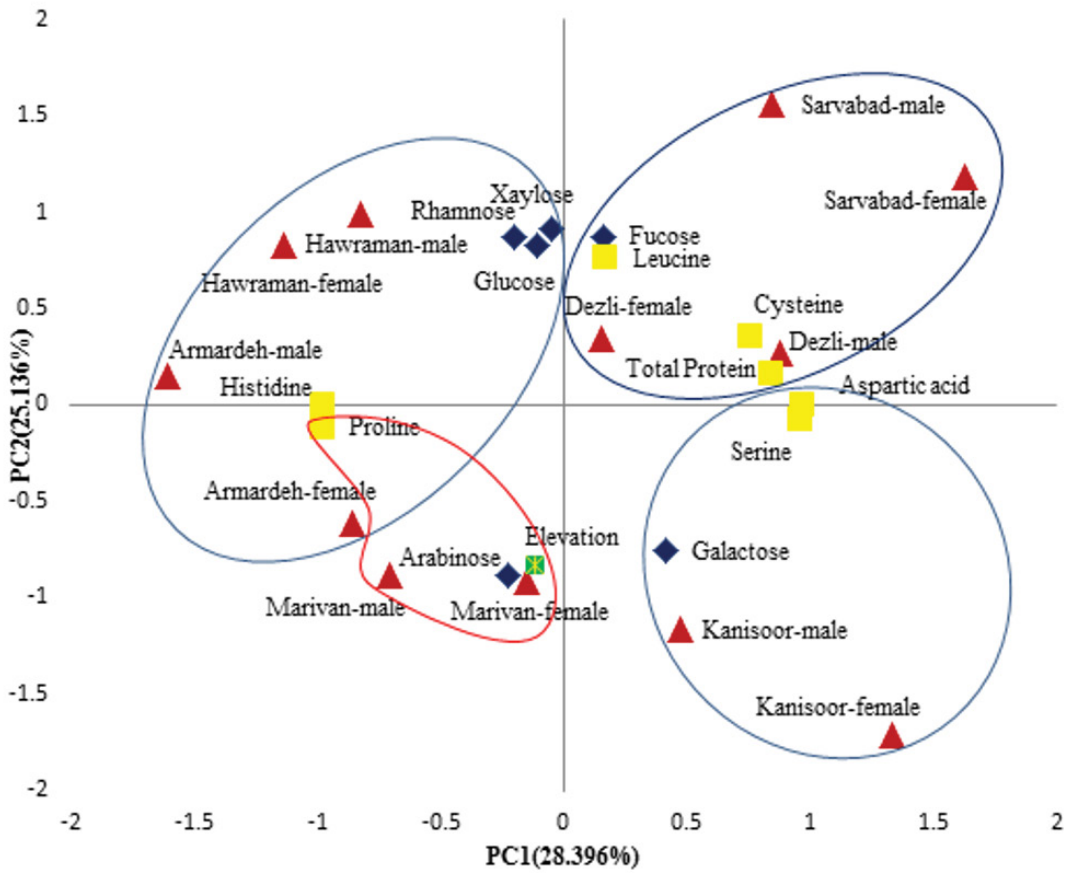

Figure 3. Principle component analysis biplot. Active monosaccharides (◆); Active amino acids (■); Active environmental characteristics (■); Active geographic regions (▲)

In Fig. 3, the gum samples of different geographic region and gender may be classified into the four following groups: the first, Dezli and Sarvabad regions, showed a positive score along PC1, where influenced by strong factor loadings value of total protein (0.845) and cystine (0.761), On the other hand fucose (0.878) and leucine (0.761) indicated a strong factor loading in the PC2. The second group consisting of Kanisoor region was assigned on the negative quadrant of PC2, strongly factor loading correlated with galactose (-0.759) and on the PC1associated aspartic acid (0.968) and serine (0.958), of course trans-verbenone indicated a strong factor loading (0.775) in the PC3 (Table 5).

The negative quadrant of PC1 indicated the third group consisting of Marivan region, where proline showed negative strong factor loadings on PC1, and on the PC2 influenced severely and srongly value by arabinose (-0.889) and environmental parameter of elevation (-0.825). Finally, in the positive quadrant of PC2 the fourth group (i.e., Hawraman and Armardeh regions) is located. This group represented high positive scores on PC2, where correlated strongly with glucose (0.822), rhamnose (0.877), xaylose (0.916) and β-pinene (0.961) on PC3, and also it influenced strong factor loadings value of histidine (-0.975) and α- pinene (-0.935) on PC1 and PC3, respectively (Table 5).

Table 5. Factor loading of active Variables after Varimax rotation

Active variables	Factor loading		
	PC1	PC2	PC1
α-Pinene	-0.061	0.046	**-0.935**
Sabinene	0.627	-0.265	0.345
β-Pinene	-0.102	0.023	**0.961**
1,8-cineole	**-0.725**	0.034	-0.313
Trans-pinocarveol	-0.657	-0.210	0.078
Trans-verbenol	0.165	-0.059	**0.775**
Arabinose	-0.225	**-0.889**	-0.176
Galactose	0.416	**-0.759**	0.207
Rhamnose	-0.202	**0.877**	-0.052
Fucose	0.166	**0.878**	-0.073
Xylose	-0.051	**0.916**	0.151
Glucose	-0.114	**0.822**	-0.014
Protein	**0.845**	0.158	0.141
Cysteine	**0.761**	0.357	0.350
Histidine	**-0.975**	0.006	0.078
Glutamine	-0.412	-0.656	0.471
Isoleucine	0.693	-0.154	0.572
Serine	**0.958**	-0.075	-0.034
Proline	**-0.975**	-0.114	-0.017
Aspartic acid	**0.968**	-0.003	-0.160
Leucine	0.174	**0.761**	0.111
DS	0.634	-0.168	0.505
SI	0.133	-0.290	**0.720**
Elevation(m)	-0.120	**-0.825**	0.045
Variability	28.396	25.136	20.420
Cumulative	28.396	53.532	73.951

Note: SI: Solar illumination during one year (MW m^{-2}); DS: Distance from the stream channel (m); underlined numbers denote moderate variables; Bold numbers denote strong variables

Based on the results of previous studies, due to the different climates condition such as elevation, solar illumination during on year, distance from the stream channel, mean annual temperature, total annual precipitation, the slope and geographical direction of growth can be the source of geological, biogeochemical and physiological changes in plants that ultimately are effective in creating such results (Critto et al., 2003; Facchinelli et al., 2001; Nadhir Gourine et al., 2010; Liu et al., 2008; Mirahmadi et al., 2019; Rahimi et al., 2013).

Yousefi (2015) studied the important properties of *P. atlantica* subsp. *kurdica* trees and fruits in two regions in Dezli and Baneh regions of Kurdistan (Iran) and showed a significant difference ($P < 0.01$) between regions for all traits including mean tree diameter (D), hollow fruit in cluster (HFP), fruit length (FL), fruit width (FWi), fruit size (FWi * FL), optimal weight fruit (FW), hollow fruit weight (HFW), skinless fruit (FWSW), seed weight (dry weight) and seed weight to fruit ratio (SW / FW) are present in regions, especially among female trees (YOUSEFI, 2001).

Physical properties

ANOVA results indicated that geographic region ($P < 0.05$) had significant effects on the surface and interfacial tension and intrinsic viscosity (Table 6). Significant differences were observed for surface and interfacial tension contents according to gender ($P < 0.05$) except intrinsic viscosity.

The gums of male trees have a higher average than the gums of female trees in terms of surface and interfacial tension.

Surface tension is a property of the liquid surface that shows how the surface molecules of a liquid are absorbed by adjacent molecules and is a factor affecting adhesion (Adhikari et al., 2007). Based on the results, the surface tension of all samples of different regions, except for the sample of Dezli region, which is slightly higher than the amount of water surface tension at 25 °C (72.5 – 71.1 mm/m). The other samples has a surface tension of half and less water surface tension (Huang et al., 2001). Based on oleoresin analysis, the surface tension in almost all samples of different regions are comparable to the surface tension of 1 % xanthan gum solution (42 mN m^{-1}) (Prud'Homme and Long, 1983) and 0.5% gum solutions of fenugreek, pectin, guar, xanthan, gum arabic, carrageenan and methylcellulose has been dtermined50.3, 53.6, 55.2, 60.8, 46.9, 65 and 52.9 mN m^{-1}, respectively (Huang et al., 2001) and basil (*Ocimum bacilicum* L.) seed gum (BSG)(57-64 mN m^{-1}) (Naji-Tabasi et al., 2016) and most of gums (45-65 mN m^{-1}) (Garti, 1999).

The intrinsic viscosity [η] of PAK gum solutions from different regions was in the range of 17.24–20.03 dL g^{-1}. This value was lower than for basil seed, kappa-carageenan, pectin and xanthan gums 39.17, 42.20, 24.5 and 110.34 (dL g^{-1}), respectively (Naji-Tabasi et al., 2016; Nickerson et al., 2004; Sato et al., 1984; Viturawong et al., 2008) and higher than Plantago major seed (PSM), cress seed, guar and fenugreek gums 19.21, 0.726, 15.80 and 15.10 (dL g^{-1}), respectively (Lapasin and Pricl, 1995; Niknam et al., 2019; Razmkhah et al., 2016).

Statistical relationships

Spearman rank correlation coefficient results among gum chemical components and physical characteristics (Surface tension, Interfacial tension, and Intrinsic viscosity) are shown in Tables 7, 8 and 9. Threonine, tryptophan, comphene, 1,8-cineole and myrtenal ($P < 0.01$) and total sugar, glucuronic acid, alanine, histidine, α-thujene, citronellel and p-cymen-7-ol ($P < 0.05$) contents display significant positive correlation with surface tension, and it showed significantly negative correlations with glucuronic acid, asparagine, arginine, leucine and sabinene ($P < 0.01$) and moisture, glycine, serine and aspartic acid ($P < 0.05$). Interfacial tension showed significantly positive correlations with myrcene, 1,8-cineole, p-cymen-7-ol, trans-carveol and tricyclene ($P < 0.01$), and Glutamine, comphene and α-terpinolene ($P < 0.05$), on the other hand, alanine, cysteine, limonene, longifolene, bornyl acetate and terpinen-4-ol ($P < 0.01$) and Phenylalanine, α-thujene and sabinene ($P < 0.05$) contents display significant negative correlation with interfacial tension. The significant positive correlation between chemical components and intrinsic viscosity was observed phenylalanine, α-pinene and cis-verbenol ($P < 0.01$) and only terpinen-4-ol ($P < 0.05$), and also, intrinsic viscosity is found to be negatively correlated with citronellal ($P < 0.01$) and valine, β-pinene and tricyclene ($P < 0.05$).

Previous studies have displayed that environment characteristics (solar illumination, elevation, mean annual temperature and total annual precipitation) have high correlation with amino acid composition (Amelung et al., 2006; Assefa et al., 2018; Cao et al., 2016; Gambetta et al., 2017; Garcia Del Moral et al., 2007; Sidle, 1967; Song et al., 2016). Also, environmental factors (solar illumination, total annual precipitation) play a main role in the content of carbohydrates production by control photosynthesis (Austin, 2002; Davis and Goetz, 1990; Lebourgeois, 2007; Li et al., 2013; Sperling et al., 2017). It is demonstrated that environmental factors will be strongly affected by climate change (Maxwell and Pesic, 2001).

Table 6. Physical properties of the extracted gum samples for factors under investigation

Sample	Gender		Geographic regions					
	Female	Male	Kanisoor	Armardeh	Hawraman	Dezli	Sarvabad	Marivan
Surface tension (mN / m)	49.72±9.23 ^{a}	38.49±12.84 ^{b}	58.40±13.30 ^{b}	30.03±4.26 ^{d}	47.26±4.12 ^{c}	75.47±5.58 ^{a}	29.97±3.37 ^{e}	25.52±7.25 ^{f}
Interfacial tension (mN/m)	21.58±1.86 ^{a}	19.36±0.56 ^{b}	19.37±0.58 ^{d}	18.96±0.13 ^{e}	20.78±0.24 ^{c}	21.20±1.21 ^{b}	18.83±0.34 ^{f}	23.70±2.80 ^{a}
Intrinsic viscosity (dL/g)	18.24±1.33 ^{a}	18.69±1.37 ^{a}	17.24±0.53 ^{c}	17.39±1.25 ^{c}	18.36±0.51 ^{bc}	20.03±1.54 ^{a}	19.12±1.24 ^{ab}	18.64±2.20 ^{abc}

Note: Values with different letters in each row are significantly different according to Tukey's HSD test at $P < 0.05$ significance level

Table 7. Matrix of Spearman's correlation coefficient for Chemical Components and Physical Characteristics

Chemical components	Physical properties		
	S. TEN	I. S. TEN	I. VIS
α-thujene	0.389	-0.383	0.101
α-pinene	-0.225	0.303	**0.479**
comphene	**0.525**	0.352	-0.230
verbenone	-0.153	0.196	0.246
sabinene	**-0.619**	-0,381	-0.073
β-pinene	0.112	-0.068	-0.340
myrcene	0.117	**0.496**	-0.119
α-phelandrene	-0.044	0.053	-0.259
p-cymen-7-ol	0.368	**0.613**	0.238
limonene	0.212	**-0.429**	0.052
1,8-cineole	0.386	**0.640**	0.125
γ- terpinene	-0.079	-0.148	0.123
α-terpinolene	-0.210	0.341	-0.282
citronellel	0.395	0.057	**-0.688**
linalool	0.063	-0.062	0.194
trans-pinocarveol	0.280	0.005	-0.180
trans-verbenol	-0.268	-0.313	-0.318
terpinen-4-ol	0.083	**-0.757**	0.389
myrtenal	**0.487**	-0.179	-0.252
α-terpenyl acetate	-0.156	-0.330	0.205
longifolene	-0.228	**-0.510**	0.200
cis-verbenol	0.146	-0.342	-0.003
trans-carveol	0.004	**0.463**	-0.238
tricyclene	0.234	**0.602**	-0.353
bornyl acetate	0.213	**-0.623**	0.231
terpinen-4-ol	0.088	**-0.757**	0.389

Note: S. TEN: Surface tension (mN m^{-1}); I. F. TEN: Interfacial tension (mN m^{-1}); I. VIS: Intrinsic viscosity (μg mL^{-1}); underlined numbers denote $P < 0.05$; bold numbers denote $P < 0.01$ significance level

Table 8. Matrix of Spearman's correlation coefficient for Chemical Components (protein and amino acids)

Chemical components	Physical properties		
	S. TEN	I. S. TEN	I. VIS
Protein	0.399	0.112	0.036
alanine	0.393	**-0.477**	-0.118
glycine	-0.370	0.230	-0.058
lysine	0.101	0.116	0.171
cysteine	0.175	**-0.499**	0.143
threonine	**0.583**	0.160	0.171
valine	0.075	-0.189	-0.335
phenylalanine	**-0.459**	-0.407	**0.448**
histidine	0.409	0.224	-0.159
glutamine	0.098	0.058	-0.275
isoleucine	0.118	-0.282	-0.036
asparagine	**-0.567**	0.218	0.025
methionine	-0.107	-0.167	0.311
serine	-0.410	-0.274	0.198
arginine	**-0.661**	0.127	-0.064
proline	-0.014	-0.014	-0.124
tyrosine	-0.278	-0.072	0.062
glutamic acid	0.192	0.371	-0.178
aspartic acid	-0.396	-0.272	0.203
leucine	0.214	**-0.471**	0.272
tryptophan	**0.629**	0.253	0.070

Note: S. TEN: Surface tension (mN m^{-1}); I. F. TEN: Interfacial tension (mN m^{-1}); I. VIS: Intrinsic viscosity (μg mL^{-1}); underlined numbers denote $P < 0.05$; bold numbers denote $P < 0.01$ significance level

In this regard, variability of environmental factors such as degree days, light and soil properties (i.e., moisture, nutrients and oxygen) will led to large variations in production of secondary compounds (Boer et al., 1992; Gambetta et al., 2017; Hanover, 1966; IPCC, 2001; Maxwell and Pesic, 2001). Studies on Iranian gums have shown that increasing the levels of some monosaccharides such as glucose, fucose, xylose and galacturonic acid increases the viscosity of the gum (Falkowski and Szafran, 2016) and increasing arabinose reduces the viscosity (Dey et al., 2003). Increases in the amino acids histidine, arginine, alanine, proline, valine, glycine, serine, acid lysine and glutamic acid can reduce viscosity (Rajagopal and Johnson, 2015; Ştefaniu et al., 2011).

Table 9. Matrix of Spearman's correlation coefficient for Chemical components (moisture, ash, sugars, glucuronic and galactouronic acids)

Chemical components	Physical properties		
	S. TEN	I. S. TEN	I. VIS
Moisture	-0.347	-0.078	-0.226
Ash	-0.018	-0.407	0.066
Total sugar	0.364	0.053	-0.007
Arabinose	-0.174	0.224	-0.061
Galactose	-0.018	-0.040	-0,072
Rhamnose	0.109	-0.170	0.117
Fucose	-0.076	-0.189	0.144
Xylose	-0.059	-0.202	0.085
Glucose	-0.146	-0.258	0.125
Glucuronic acid	0.413	-0.035	0.203
Galacturonic acid	**-0.715**	-0.091	-0.091

Note: S. TEN: Surface tension (mN m^{-1}); I. F. TEN: Interfacial tension (mN m^{-1}); I. VIS: Intrinsic viscosity (μg mL^{-1}); underlined numbers denote $P < 0.05$; bold numbers denote $P < 0.01$ significance level

Table 10. Matrix of Spearman's correlation coefficient for Physical characteristics

Physical properties	Physical properties	
	I. F. TEN	I. VIS
Surface tension	0.062	-0.050
Interfacial tension		-0.265
Intrinsic viscosity		

Note: I. F. TEN: Interfacial tension (mN m^{-1}); I. VIS: Intrinsic viscosity (μg mL^{-1}); underlined numbers denote $P < 0.05$; bold numbers denote $P < 0.01$ significance level

The results show that the presence of ionic and non-ionic amino acids can affect surface and interfacial tension (Al Husseini, 2015). Therefore, based on the environmental results of this study, difference in geographic regions of sampling were caused changes in chemical compounds and, consequently, changes in the physical factors under study.

Conclusion

In this study, for the first time, the chemical and physical properties of *Pistacia atlantica* subsp. *kurdica* gum were carefully investigated from the female and male trees of different regions of Kurdistan province, Iran. The results of environmental and geographical analysis showed a significant difference between of the sampling different regions, and also, the significant difference determined between gum samples of different regions and gender.

Cluster analysis divided the sampling different regions into four cluster, representing Sarvabad and Howraman, Kanisoor, Dezli and Armardeh and Marivan cluster, respectively. The PCA groups, are significantly influenced by strong variables of amino acids, volatile components, carbohydrates and environmental factors. Significantly difference was indicated between different regions and gender for physical properties (Surface tension, Interfacial tension, and Intrinsic viscosity). The results of spearman's correlation coefficient showed that physical properties correspond a significant positive or negative correlation with most of chemical components. Finally, it is suggested, based on the results of this study, the gum extraction is carried out separately for different geographical regions and tree gender.

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