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Fractionation and Determination of Some Structural Properties of Persian Gum

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ABSTRACT: In the present study, Persian gum, an exudate gum which secrets from the mountain almond tree (*Amygdalus scoparia* Spach) from two different regions is evaluated by means of chemical and instrumental analysis (fractionated by solving in water and alkaline solutions at 0.1, 0.5 and 1 M and also Smith degradation) using HPLC, ^{1}H–NMR and ^{13}C–NMR spectroscopy's. The total sugar and uronic acid content of the gum are 88.70 and 10%, respectively. The results of the instrumental analyses revealed that the gum is predominantly composed of galactose and also (1→3) linked β-D–Gal*p* and rhamnose residues that exist at the backbone of polysaccharide where as the branches are composed of (1→6) linked β-D–Gal*p* and (1→) and/or (1→3) linked α-L-Ara*f* residues. Therefore, due to the desirable structure of Persian gum (arabinogalactane) that is similar to the other hydrocolloids, it might be employed in food products.

Keywords: *Amygdalus scoparia Spach, Intrinsic Viscosity, NMR Spectroscopy, Persian Gum, Smith Degradation.*

Introduction

Persian gum is a kind of exudate gum which secretes from the bark and branches of mountain almond tree (*Amygdalus scoparia* Spach); a tree from Rosaceae family. This tree grows wildly at the regions with semi-arid and dry-warm Mediterranean climate such as Iran and central Asia. It has some pharmaceutical, nutritional and industrial applications as well as traditional medicine usages (Abbasi & Rahimi, 2008; Rahimi *et al*., 2013).

The polysaccharide gums are composed of vast monosaccharide residues that are linked together by *O*-Glycosidic joints (Izydorczyk *et al*., 2006) which the ratio of monosaccharide's and also the kind of Glycosidic linkages induce their structural variation (Simas *et al*., 2008); the structural variations in polysaccharides is an agent for creating some of their specific functional characteristics (Izydorczyk *et al*., 2006). Nowadays the new knowledge at molecular dimension of chemical/functional properties of polysaccharide gums provides a better choice for preparation of ideal biopolymer through the special industrial needs. Moreover, in accordance with the benefits of users, these polymers are completely natural hence the food scientists and technologists are always searching to find new resources of polysaccharides with improved functional properties, synergistic interactions, etc (Medina-Torres *et al*., 2000).

Although, over the past few years, some reports have been published about structural properties of the exudate gums from the

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trees of Rosaceae family such as peach and nectarine (Simas *et al*., 2008; Simas -Tosin *et al*., 2009; Qian *et al*., 2011), but with the best of our knowledge, no report or scientific research has been presented on Persian gum. Therefore, in the present study it is aimed to determine some structural properties of Persian gums that are collected from two regions in Iran (Fars and Eastern Azarbayjan provinces) by means of some chemical and instrumental analyses.

Materials and Methods

- *Collecting, separating and milling the gums*

The exudated gums from the bark of mountain almond trees have been collected between August to September (2010) in Fars (Larestan and Jahrom plains) and eastern Azerbaijan (Arasbaran forests) provinces, packed in nylon bags and kept at the fridge prior to the analysis. Because of the extensive variation in the color of the gums, only complete white gums (degree 1) are used in this research, which consecutively, are coded as F1 and A1 in this paper. The gums are powdered in two stages using Falling number AB (Box 5101 model, Sweden) and Agromatic AG (AQC 109 model, Germany) mills. The powders are passed through sieve nests (Damavand, Iran) and the particles smaller than 250 microns (mesh No. 60) are collected and used for further analysis.

- *Determination of some structural properties of Persian gum by chemical analyses*

- *Fractionation*

First, on the basis of Qian *et al*. (2011) and Guo *et al*. (2008) and by some modifications, the solubility rate of the gum in water and NaOH solutions at 0.1, 0.5 and 1 M (Merck Chemicals Co., Darmstadt, Germany), were determined for purification of F1 and A1 to attain pure polysaccharide fractions (Figure 1). The pH of all of the fractions were adjusted to 4.8-4.9 (regarding the initial pH of the fraction) and after precipitation by the addition of ethanol, they were dried at 40 °C and powdered. Finally, each fraction is weighed and it's the yield is calculated (Qian *et al*., 2011; Guo *et al*., 2008).

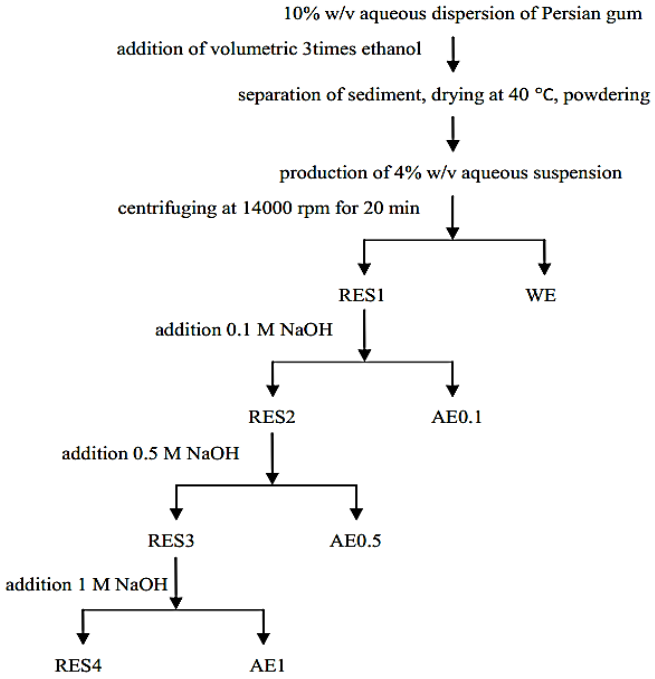

Fig. 1. Schematic fractionation of Persian gum by its solubility in water and in alkaline.

- *Smith degradation*

Exactly 2 g of the WE, AE0.1, AE0.5, AE1 and RES4 of the gums, F1 and A1, is dispersed in 200 mL distilled water which then will be oxidized by the addition of 200 mL 0.1 M sodium methaperiodate (Merck Chemicals Co., Darmstadt, Germany) in darkness and kept in the refrigerator at 4 °C for 72 h to retard the oxidation. 35 mL ethylene glycol (Merck Chemicals Co., Darmstadt, Germany) is added and after 2 h, they will be dialyzed (Sigma dialysis bag, D0405, USA, 12400 MWCO) against tap water for 48 h. Afterwards, to reach the pH of 10, the sodium borohydrid (Merck Chemicals Co., Darmstadt, Germany) is added and kept overnight to complete reducing reactions. The aqueous 10% v/v acetic acid solution (Merck Chemicals Co., Darmstadt, Germany) is added for neutralizing and they are dialyzed again for 48 h (24 h against tap water and 24 h against distilled water). Each polysaccharide is concentrated by a rotatory evaporator (Heidolph, Laborota 4000, Germany) to 20 mL and then its pH is decreased to 2 by the addition of 0.5 M trifluoroacetic acid (Merck Chemicals Co., Darmstadt, Germany) which is hydrolyzed at 96 °C in water bath (Memmert, WHB 22, Germany) for 40 min and then the 1 M NaOH solution is added to reach the pH of 5. It is concentrated again to 15 mL and finally it is precipitated by the addition of 3 volumetric times of ethanol (Simas *et al*., 2004; Karácsonyi and Kunaik, 1994). The precipitated polysaccharide is dried at 40 °C for a long time and then it is powdered; afterwards, the polysaccharide I yield is calculated regarding the initial weight. The word S before each fraction is the sign of the polysaccharide I which is prepared by Smith degradation.

- *Total sugar determination*

Using the classic Phenol-sulphuric acid method, 1.0 mg of F1 and A1 gums, and their WE, AE0.1, AE0.5, AE2, RES4 fractions and polysaccharide I which were prepared by Smith degradation as well as Arabic gum as a control, are weighed in test tubes. Then 1 mL of distilled water, 1 mL of 5% w/v aqueous phenol solution (Merck Chemicals Co., Darmstadt, Germany) and 5 mL of concentrated sulfuric acid (Merck Chemicals Co., Darmstadt, Germany) were added to each test tube. After 10 min of shaking, they were heated in water bath at 25–30 °C for 10–20 min till the orange color appeared. The absorbance was measured by a Spectrophotometer (Sinco, UVS-2100), connected to a UV-Vis detector (South Korea) at 490 nm and was compared bto glucose standards (Dubois *et al*., 1956).

- *Uronic acid determination*

Using *m*-hydroxydiphenyl method on the basis of the Blumenkrantz & Asboe-Hansen method (1973), 1.0 mg of F1 and A1 gums, the WE, AE0.1, AE0.5, AE2, RES4 fractions and polysaccharide I that were prepared by Smith degradation as well as Arabic gum as a control, were weighed in test tubes. Then, 1 mL distilled water was added to each tube and cooled in an ice bath for a few minutes. 6.0 mL of 0.0125 M sodium tetraborate (Merck Chemicals Co., Darmstadt, Germany) that has been dissolved in concentrated sulfuric acid is added and transferred into ice bath again and it is then shaken completely. The tubes were heated at 100 °C water bath for 5 min and again were cooled in an ice bath. 100 µL of 0.15% w/v *m*-hydroxydiphenyl that has been prepared in 0.5% w/v NaOH is added to each tube and it is shaken. After 20 min the absorbance of the samples were read at 520 nm in comparison to galacturonic acid standards (Brummer and Cui, 2006).

-Determination of some structural properties of Persian gum by instrumental analyses

- *HPLC chromatography*

In order to hydrolysis of the samples, 0.050 g of F1, A1 and their polysaccharide I

which were degraded by Smith degradation were weighed in headed test tubes and then 8 mL of 4% w/w sulfuric acid was added and kept at 100 °C in water bath for 4 h. For neutralization, 1.0 g of barium carbonate (Merck Chemicals Co., Darmstadt, Germany) was added to each tube and it was shaken overnight at room temperature. Finally, the hydrolysate passes through a 0.45 μm filter and is injected to HPLC (Knauer, Germany, connected to RI detector, K-2301) (Flindt *et al*., 2005). Using the following conditions; 100% water as the mobile phase with flow rate of 0.3 mL/min and injection volume of 20 μL and column temperature of 50 °C for and ambient temperature for RI detector.

- *NMR spectroscopy*

The whole gums, F1 and A1 and their polysaccharide I were transferred into 5 mm probes and solved in D_2O for catching ^{1}H–NMR and ^{13}C–NMR spectrums (Bruker, Avance DRS 500, Germany) at 25 °C which their chemical shifts (ppm) have been determined in accordance with TMS.

- *Determination of intrinsic viscosity*

All the fractions of F1 and A1 without RES4 were dissolved in distilled water for producing 1% w/v solutions that after complete hydration, some dilutions such as 0.01, 0.03, 0.05, 0.07 and 0.09 g/dL were prepared. The kinematic viscosity was measured by a Cannon-Fenske capillary viscometer (Fisher, Germany) in a 28± 0.01°C water bath that followed the calculation for determining the intrinsic viscosity (Wang and Cui, 2006).

- *Statistical analysis*

The statistical analysis, the SPSS 16.0 software and one-way ANOVA were used. In case of significant differences between the samples ($p<0.05$), Duncan test is applied. All the curves are plotted using Excel 2007.

Results and Discussion

- *Chemical analysis of the gum concerned with its structure*

The alcoholic precipitation yield (by average 94.24%) showed that this process could purify the whole gum by removing the low molecular weight composition that were dissolved in alcohol and finally simplifies the polysaccharide structure. The total sugars (by average 88.67%) as well as the uronic acid content (by average 9.81%) of Persian gum were different from Arabic gum (81.37± 0.53 and 14.94± 0.26%, respectively).

In accordance with Table 1, both fractions from the gum of Fars and Eastern Azarbayjan provinces have not meaningful quantitative differences about the fractionation yield, since the monosaccharide composition of them might be similar and the region of growth have not affected the polysaccharide structure; whereas between the five fractions of each gum there is a trend such as WE>AE0.1>RES4>AE0.5>AE1. Qian and coworkers (2011) reported that it cannot be explained that whether the fractionation of gum by alkaline solutions cause the polysaccharide depolymerization or simply break the non-covalent joint interactions among the polysaccharide chains (Qian *et al*., 2011). It is considerable that among different fractions of Persian gum, the RES4 have the highest uronic acid content (averagely 4.16%) (Table 1).

Usually the Smith degradation removes the low molecular weight components and oligomeric species by dialysis (de Paula *et al*., 1998); therefore the yield of polysaccharide I produced by Smith degradation for all the fractions is low (Table 2) and as well as the previous sections, both fractions of the gum from two different region growth show similar results. As it is shown in Table 2, the total sugar and uronic acid content of polysaccharide I was decreased comparatively to their fractions

(Table 1) due to the breakage and elimination of some chemical links during oxidation-reduction reactions which was carried out at Smith degradation. Qian et al. (2011) reported that the total sugar of the WE, AE0.1 and AE0.5 of peach gum were 85.67%, 84.21% and 82.26%, consecutively that are near to the Persian gum results. Moreover, except S-RES4 which showes a different structure from the other fractions, the uronic acids of the other polysaccharides have been removed completely from the polysaccharide structure during Smith degradation which demonstrates that probably the most content of uronic acids are concentrated in the the lateral branches that was removed simply by chemical attacks.

- *Instrumental analysis of the gum concerned with its structure*

On the basis of HPLC results, the amount of galactose at whole Persian gums, F1 and A1, are 28.20 and 29.53%, respectively, that shows their similarity in chemical structure. It is substantial that the biggest pick in the HPLC chromatograms of all of the polysaccharide I of the fractions belonged to galactose sugar residue (Table 2), in addition; in many papers it is reported that High amount of galactose monosaccharide is a very common characteristic in most polysaccharide gums (Añez *et al*., 2007; Gutiérrez de G *et al*., 2005). Also, some researches on the structural properties of the

Table 1. Fractionation yields, total sugar and uronic acid content of each fraction of Persian gum from Fars and Eastern Azarbayjan provinces

	Fars					Eastern Azarbayjan				
	WE	**AE0.1**	**AE0.5**	**AE1**	**RES4**	**WE**	**AE0.1**	**AE0.5**	**AE1**	**RES4**
Fractionation yield (%)	32.21± 0.70 [a]	27.59± 0.66 [b]	14.43± 0.63 [d]	6.70± 0.85 [e]	17.08± 0.57 [c]	32.66± 0.66 [a]	28.03± 0.26 [b]	14.73± 0.04 [d]	6.35± 0.12 [e]	16.62± 0.55 [c]
Total sugar (%)	96.00± 0.35 [b]	94.75± 0.71 [d]	94.87± 0.17 [d]	97.12± 0.53 [a]	93.12± 0.17 [e]	95.62± 0.17 [c]	95.00± 0.00 [c]	95.37± 0.87 [c]	97.12± 0.17 [a]	92.75± 0.35 [f]
Uronic acid (%)	2.06± 0.09 [b]	2.00± 0.17 [b]	1.00± 0.18 [d]	1.18± 0.08 [c]	4.19± 0.09 [a]	2.31± 0.08 [b]	2.06± 0.08 [b]	1.00± 0.08 [d]	1.25± 0.17 [c]	4.12± 0.18 [a]

Different small letters at each row show significant differences *(p<0.05).*

Table 2. The Smith degradation yield, total sugar, uronic acid and galactose content of the polysaccharide I produced by Smith degradation from each fraction of Persian gum

	Fars					Eastern Azarbayjan				
	S-WE	**S-AE0.1**	**S-AE0.5**	**S-AE1**	**S-RES4**	**S-WE**	**S-AE0.1**	**S-AE0.5**	**S-AE1**	**S-RES4**
Smith degradation yield (%)	22.10± 0.14 [a]	20.90± 0.85 [b]	15.42± 0.74 [d]	12.92± 0.60 [e]	18.67± 0.88 [c]	22.90± 0.85 [a]	21.17± 0.39 [b]	15.00± 0.28 [d]	12.59± 0.43 [e]	18.47± 0.81 [c]
Total sugar (%)	83.87± 0.17 [c]	85.87± 0.20 [a]	83.77± 0.07 [c]	83.87± 0.27 [c]	80.89± 0.17 [d]	84.12± 0.07 [b]	85.75± 0.35 [a]	84.00± 0.25 [b]	84.77± 0.87 [b]	80.62± 0.20 [d]
Uronic acid (%)	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]	2.12± 0.17 [a]	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]	0.00± 0.00 [b]	1.94± 0.09 [a]
Galactose (%)	43.13	41.40	44.04	51.40	52.77	42.02	50.30	45.47	44.39	51.32

Different small letters at each row show significant differences *(p<0.05).*

exudate gums which are from the same family of Persian gum (Rosaceae) like peach and nectarine gums, reported the acidic arabinogalactane structures (Simas *et al*., 2008; Qian *et al*., 2011; Simas–Tosin *et al*., 2009) that is very near to the Persian gum chemical structure. Since the amount of galactose in polysaccharide I is more than the whole gum, hence it can be demonstrated that probably, galactose is a main unit at the backbone of Persian gum which some sever treatments like fractionation and Smith degradation, nevertheless elimination of branches, couldn't completely remove it from the internal segments of the polymer network and instead increased its accessibility at polysaccharide I. Unfortunately, because of the poor equipments the measurement of the other monosaccharide was not possible.

The ^{1}H–NMR spectrum of S–WE of A1 is shown in Figure 2 (A), which according to Brummer and Cui (2006), it can be found out that the number of β–anomeric protons (δ 4–5 ppm) are more than α–anomeric ones (δ 5–6 ppm) (Brummer and Cui, 2006); hence it is predicted that the predominant protons are β in this polysaccharide as well as all of the other ^{1}H–NMR spectrums of polysaccharides which have very similar signals. All of the spectrums expect whole gums have a fine signal at chemical shift at the range of 1.0–1.1 ppm, which is attributed to the methyl group protons of rhamnose (Martínez *et al*., 2003). The ^{1}H–NMR spectrums of the whole gums, F1 and A1, are very complex in comparison to their polysaccharide I of fractions which might have resulted from the extensive structural complexity or high molecular weight of whole gums. It is demonstrated that the region growth of the gums has no significant difference on their ^{1}H–NMR spectrums, too.

The ^{13}C–NMR spectrum of S–WE of A1 is shown in Figure 2 (B), which the number of β–anomeric carbons (δ 100–105 ppm) are more than α–anomeric carbons (δ 95–100 ppm) (Cui, 2006). This again justifies the dominance of β links among the polysaccharide network. Except whole gums, the entire spectrums have a signal at 16.5–17.5 ppm which is demonstrative of the rhamnose residue (Gutiérrez de G *et al*., 2005; Larrazábal *et al*., 2006; Kang *et al*., 2010) that was discussed above. Rhamnose residue probably is at the backbone of the polysaccharide, because it was appeared at the polysaccharide I after simplifying the complex structure of the whole gum during Smith degradation. Only at the spectrums of whole gums and S-RES4, a fine signal is observed at 170–180 ppm, which is attributed to uronic acids (Cui, 2006) and affirms the results of previous section about uronic acid content. Totally, the spectrums of polysaccharide I of fractions produced by Smith degradation were simpler and better than the whole gums, as it was reported by León de Pinto *et al*., (2001). On the other hand, the ^{13}C–NMR spectrums of various fractions of persian gum have a close chemical similarity as reported by Simas *et al*., (2008) for peach gum and Simas–Tosin *et al*., (2009) for nectarine gum.

Based on the documents concerned with the chemical shifts of ^{13}C–NMR spectrums, Table 3 evidences the existence of β-D–(1→3) galactopyranose, (1→6) and α-L–(1→3) arabinofuranose, (→1) in the polysaccharide structure of Persian gum. According to Table 3, there isn't β-D–(1→3)galactopyranose at the whole gums, F1 and A1, while it exists in their polysaccharide I, hence it can be concluded that the situation of this sugar residue is in the backbone of polysaccharide; whereas the other residues presented in Table 3, assignes to the entire amount of persian gum polysaccharides that means they are at the main chain of polysaccharide and branches. Similarly, it is reported that the main chain of peach gum is constructed by β-D–(1→6)galactopyranose (Simas–Tosin *et al*., 2009).

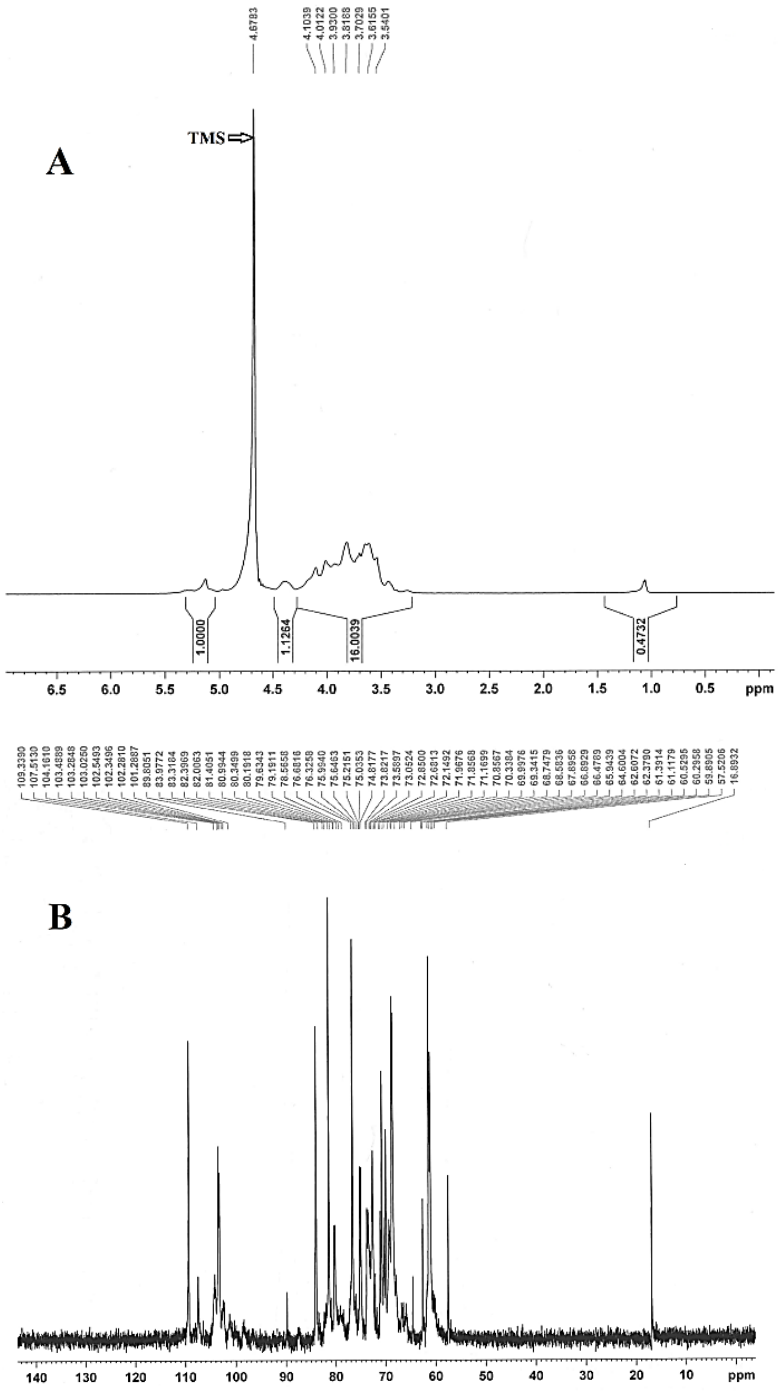

Fig. 2. The ^{1}H (A) and ^{13}C (B) NMR spectrums of S-WE of A1 gum

- *Intrinsic viscosity*

Intrinsic viscosity is calculated for all the fractions of F1 and A1, except RES4, (Table 4) on the basis of the curves of η_{sp}/c and $\ln(\eta_{rel})/c$ against concentration.

The rheological behavior of a solution can be regarded as a point for recognizing the properties of the polysaccharide in the solution because special polysaccharides show behavior proportionate to the specific molecular structure (Brummer and Cui,

Table 3. Assignment of ^{13}C–NMR chemical shift values (ppm) of Persian gum polysaccharides according to some references (a–d)

		Fars						Eastern Azarbayjan					
	Ref.	**F1**	**S-WE**	**S-AE0.1**	**S-AE0.5**	**S-AE1**	**S-RES4**	**A1**	**S-WE**	**S-AE0.1**	**S-AE0.5**	**S-AE1**	**S-RES4**
→1)β-D-Gal*p*(3→ : C-1 [a]	**104.6**	-	104.16	104.40	104.63	103.49	104.53	-	104.16	104.13	104.32	104.17	104.34
# : C-2 [a]	**70.9**	-	70.36	70.83	70.84	70.84	70.85	-	70.85	70.84	70.85	70.85	70.86
# : C-3 [a]	**82.7**	-	82.1	83.36	82.15	82.39	82.16	-	82.39	82.19	82.02	82.00	82.06
# : C-4 [a]	**69.1**	-	69.22	69.14	69.10	69.42	69.31	-	69.34	69.34	69.31	69.33	69.33
# : C-5 [a]	**75.4**	-	75.55	75.32	75.55	75.19	75.65	-	75.21	75.22	75.22	75.22	75.22
# : C-6 [a]	**61.6**	-	61.40	61.40	61.40	61.36	61.38	-	61.39	61.78	61.60	61.60	61.71
→1)β-D-Gal*p*(6→: C-1 [b]	**102.7**	102.74	102.63	103.28	102.62	103.23	102.77	102.69	102.54	102.77	102.77	102.45	102.74
# : C-2 [b]	**70.1**	69.92	69.99	69.94	69.98	69.95	69.99	70.43	69.99	69.98	69.99	69.96	70.00
# : C-3 [b]	**72.5**	72.63	72.68	72.66	72.51	72.68	72.67	72.55	72.68	72.55	72.68	72.55	72.71
# : C-4 [b]	-	-	-	-	-	-	-	-	-	-	-	-	-
# : C-5 [b]	**73.1**	70.03	73.58	73.52	73.58	73.59	73.57	73.03	73.05	73.04	73.04	73.05	73.57
# : C-6 [b]	**68.7**	68.69	68.74	68.73	68.73	68.73	68.74	68.72	68.74	68.74	68.75	68.75	68.75
→3)α-L-Ara*f*(1→: C-1 [c]	**109.0**	109.21	109.34	109.33	109.37	109.32	109.56	109.49	109.33	109.32	109.34	109.34	109.34
# : C-2 [c]	**80.9**	80.33	80.98	80.98	81.00	80.33	80.99	81.38	80.99	81.00	81.00	81.01	80.98
# : C-3 [c]	**83.7**	84.10	83.33	83.35	83.33	83.96	83.73	82.92	83.31	83.97	83.74	83.72	83.73
# : C-4 [c]	**83.7**	84.10	83.98	83.98	83.99	83.96	83.97	83.62	83.97	83.97	83.74	83.72	83.73
# : C-5 [c]	**62.2**	62.53	62.60	62.60	62.60	62.59	62.60	62.07	62.37	62.60	62.60	62.61	62.40
α-L-Ara*f*(1 →: C-1 [d]	**109.2**	109.21	109.34	109.33	109.37	109.32	109.56	109.49	109.33	109.32	109.34	109.34	109.34
# : C-2 [d]	**81.2**	81.41	81.40	81.10	81.00	81.39	81.19	81.38	81.40	81.40	81.40	81.41	81.41
# : C-3 [d]	**76.5**	76.47	76.69	76.68	76.69	76.68	86.68	76.46	76.68	76.68	76.68	76.32	76.35
# : C-4 [d]	**83.8**	84.10	83.98	83.98	83.99	83.96	83.73	83.62	83.97	83.97	83.74	83.72	83.73
# : C-5 [d]	**81.2**	81.41	81.11	81.10	81.41	81.39	81.19	81.38	80.99	81.00	81.00	81.01	80.98

[a] de Paula, Santana & Rodrigues, 2001; [b] Martínez *et al.*, 2003; [c] Gutiérrez de G *et al.*, 2005; [d] León de *Pinto et al.*, 2000.

Table 4. The intrinsic viscosity of water extractable and alkaline extractable fractions of Persian gum

	Fars				Eastern Azarbayjan			
	WE	**AE0.1**	**AE0.5**	**AE1**	**WE**	**AE0.1**	**AE0.5**	**AE1**
Intrinsic viscosity (dL/g)	7.08± 0.87 [d]	9.22± 0.89 [c]	11.33± 0.58 [b]	13.33± 0.55 [a]	6.77± 0.91 [d]	9.12± 0.54 [c]	11.08± 0.13 [b]	12.91± 0.35 [a]

Different small letters at each row show significant differences *($p<0.05$).*

2006). Table 4 shows that the intrinsic viscosity increases from WE fraction toward AE1 for both gums, F1 and A1; this is probably derived from the molecular weights of the fractions that have higher molecular weight, higher intrinsic viscosity and/or high compression of the molecular structure or the number of branches that cause to increase the intrinsic viscosity. Similar to the previous results, the intrinsic viscosity of the fraction F1 does not have meaningful difference with A1.

Conclusion

The chemical structure of the Persian gum has been studied and the results of some chemical and instrumental analyses demonstrated that it is a polysaccharide gum with 10% uronic acid that exists at the sub-chains of the polymer network. The results of NMR spectroscopy elucidates that the backbone of the polysaccharide gum is constructed by (1→3) linked β-D–Galp and rhamnose residues whereas the branches are composed of (1→6) linked β-D–Galp, (1→3) linked α-L–Araf and terminal α-L–Araf. Further studies are required to focus on the detailed structure of Persian gum and its fractions to explore their potential as a natural gum that might be employed in food systems.

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