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Effect of Concentration and Temperature on the Rheological Flow Behavior and Dynamic Oscillatory Properties of purified Alooche Exudate Gum

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ABSTRACT

The *Rosaceae* family includes numerous species such as peach, apricot, plum, cherry, and almond, which are well known for producing natural gums. *Prunus cerasifera* is one of the gum-producing species, and its exudate is a clear, mucilaginous liquid with a light-yellow color. In the present study, the rheological properties of raw and purified *Prunus cerasifera* gum were evaluated at concentrations of 4%, 6%, and 8% and at temperatures of 5°C and 85°C. Flow behavior, strain sweep, and frequency sweep tests were performed to investigate the mechanical behavior of the samples. Furthermore, FTIR spectroscopy was used to identify functional groups, along with zeta potential measurements and color analysis. The results showed that all samples exhibited pseudoplastic (shear-thinning) behavior. Among the rheological models applied, the Herschel–Bulkley, Power-law, and Sisko models provided the best fit with the highest coefficients of determination (R^2). Increasing the gum concentration from 4% to 8% led to an increase in both storage and loss moduli, while increasing the temperature resulted in a decrease in these moduli. FTIR findings confirmed the presence of carbohydrate-related functional groups and the characteristic fingerprint region of cherry plum gum.

1-Introduction

From a technical and industrial perspective, gums are defined as plant or microbial polysaccharides that can effectively dissolve in hot and cold water to form viscous solutions. Plant gums are usually secreted from the bark, branches, and fruits of trees as a protective mechanism against mechanical and microbial damage. These secreted gums are one of the oldest and most traditional thickening and stabilizing agents used in the food industry. Despite competition from synthetic gums and other natural gums, many of these secreted gums continue to be used in significant quantities due to their unique properties and functions [1].

Gum production can be increased by making incisions in the bark of trees or by removing it from trees and shrubs. Plant gums are hydrophilic carbohydrates of high molecular weight, usually composed of monosaccharide units linked by glycosidic bonds. These gums have several properties, including non-toxicity, non-irritation, low cost, stability, biodegradability, biocompatibility, and environmental friendliness, which make them preferable to synthetic and semi-synthetic polymers. Secretory gums have been used in various fields for decades and have retained their importance despite the emergence of alternative gums with similar properties [1].

Various families such as*Leguminosae*، *Sterculiaceae*، *Anacardiaceae*، *Combretaceae*، *Meliaceae*، *Rutaceae*and*Rosaceae*Produces gum. The production of large amounts of gum by stone fruit trees of the Rosaceae family has attracted the attention of botanists and horticulturists for over 100 years. Plants of the family*Rosaceae*The most studied include cherries, plums, apricots, peaches, and almonds. Based on their solubility in water, gums are classified into three categories: soluble, insoluble, or semi-soluble gums. Semi-soluble gums first form a swollen gel and then become soluble when more water is added. Gums of the Family*Rosaceae*They are usually insoluble in oils or organic solvents (such as hydrocarbons, ethers, or alcohols), while they are either soluble in water or absorb water (swell or disperse in cold water to form a viscous solution or gel) [2].

Plum tree is a species of tree.*virescence*In India. Plum tree gum is a highly transparent mucilaginous liquid with a light yellow color. Species*Prunus*Related To the family*Rosaceae*It produces a secreted gum called gummosis due to a phenomenon called gummosis. This secreted gum is extracted from the branches of the*Prunus*It is obtained especially from damaged or infected parts. Gum exudates are mainly composed of polysaccharide compounds containing arabinose and galactose in different proportions [3]. The general structure of most of these gums is composed of substituted arabinogalactan. Gums*Prunus*In some countries it is used in combination with other gums such as gum arabic, gum gati and tragacanth in India. The rheological properties of hydrocolloids in solution depend on many factors including the concentration of the active compound, temperature, degree of dispersion, solubility, electrical charge, previous thermal and mechanical treatment, presence or absence of other lyophilic colloids, and the presence of electrolytes and non-electrolytes. In this study, the physicochemical and rheological properties of purified secretory gum of plum have been investigated.

2- Materials and methods

1-2- Extraction of plum gum and purification

Gum secreted from the trunks of plum trees*(Prunus cerasifera*) located in the gardens of Babol city. The samples were first dried in an oven at 55°C for 24 hours. After drying, the gums were ground and turned into a uniform powder. For extraction, the gum powder was dissolved in distilled water at a concentration of 10% (w/v) and the resulting mixture was stirred on a magnetic stirrer for 2 hours. Then the solution was kept at room temperature for 24 hours to complete the hydration process. Then the sample was centrifuged for 10 minutes at 4000 rpm. The supernatant (solution containing dissolved gum) was collected and for purification, three times the volume of absolute ethanol was added to it to perform the precipitation process. The mixture was left at room temperature for 2 hours to form a gum precipitate. Finally, the precipitate was separated and dried in an oven at 45°C.°C was dried for 24 hours. The resulting dry powder was purified plum gum, which was used for subsequent tests.

2.2- Fourier Transform Infrared Spectroscopy (FT-IR)

FT-IR measurement using a device (desktop FT-IR spectrometer, model CARY 630, manufactured by Agilent, USA) in the cm wavelength range^{-1}650-4000 will be done.

3-2- Zeta test

Zeta potential was measured using a device (Zeta Sizer, Malvern Company, England) at a temperature of 25 degrees and pH 7. To perform the zeta test, 0.1% solutions of crude and purified gum were prepared and stirred on a stirrer for 24 hours.

4-2- Colorimetric test

The color of the gum powder was done using a device equipped with a digital camera. For this purpose, the samples were placed in the middle of the device and images were taken using a digital camera with a resolution of 16 and in jpg format in RGB color space. The images were converted from RGB to L a b color space using Image j software and the program (color-space-convertor). The color values L*, the whiteness and brightness index, range from zero to 100, and the a* index ranges from minus 120 to plus 120, with positive values for red colors and negative values for green colors. The b* parameter has positive values for yellowness and negative values for blue [4].

Chroma is calculated according to the following equation:

$$C^* = \sqrt{a*^2 + b*^2} \qquad (1)$$

In this equation, a* is the brightness index, b* is the yellowness index, and a* is the redness index.
BI was calculated according to the following equation (Mohapatra et al., 2010):

$$BI = 100 \times \left(\frac{X - 0.31L}{0.17}\right) \qquad (2)$$

In which the x index was calculated according to the following equation:

$$X = \frac{(a* + 1.75L)}{(5.645L + a* - 3.012b*)} \qquad (3)$$

5-2- Rheology tests

To perform rheology tests, a rotational rheometer (Physica MCR-301 model, manufactured by Anton Paar, Austria) was used, equipped with a thermal circulator for temperature control and a parallel plate probe. A Peltier plate system with a sensitivity of 0.01 was used to adjust the temperature.±Equipped with a water circulator (Viscotherm VT2) was used. For data analysis, Matlab software (8.4.0.150421) R2014b was used. Solutions of 4, 6 and 8% gum were prepared and stirred on a stirrer for 2 hours and kept at room temperature for 24 hours. Then it was placed in a refrigerator at 4 ° C for 24 hours [5].

1-5-2- Flow behavior test

Flow behavior measurements were performed at shear rates of 0.1 to 300/s at temperatures of 5 and 85°C. Power law, Casson, Herschel Bulkley, and Bingham and Cisco models were fitted using Matlab software.

1-Powerla model

$$\tau = k_p \dot{\gamma}^{n_p} \qquad (1)$$

In this equation K_pConsistency coefficient (Pa s^n) and n_p، is the flow behavior index (dimensionless). K is the magnitude of the fluid viscosity and n represents the fluid behavior characteristic.tShear stress (N/m^2) and$\dot{\gamma}$The shear rate is 1/s.
2- Herschel Bulkley model
Herschel-Bulkley's model: $\tau = K_{OR}(\dot{\Upsilon})^{n_{OR}} + \tau_{0H}$ (2)
In this equation K_H ،, consistency coefficient (Pa s^n) and n_H، is the flow behavior index (dimensionless). K is the magnitude of the fluid viscosity and n represents the fluid behavior characteristic.τ_{0H}The yield stress (Pa) for the Herschel Bulkley model isτShear stress (N/m^2) and$\dot{\gamma}$The shear rate is 1/s.
3-Bingham model
Bingham: $\tau = \eta_\beta \dot{\Upsilon} + \tau_{0b}$ (3)
In this equationη_BBingham viscosity (Pa s) andτ_{0B} The yield stress (Pa) is the Bingham model.
4-Casson model
Casson model: $\tau^{0.5} = K_{0c}^{0.5} + k_c\ (\dot{c})^{0.5}$ (4)
In this equation $k_{0c})^2)= \tau_{0c}$Indicates the yield stress (Pa) and = (k_c^2) η_cIt is called the Casson viscosity (Pa s).τShear stress (N/m^2) and$\dot{\gamma}$The shear rate is 1/s.
5-Cisco model
Sisko: $\tau = \eta_\infty \dot{\Upsilon} + K_S\, \Upsilon^{n_s}$ (5)

In this equation K_s ،, consistency coefficient (Pa s^n) and n_s، It is a flow behavior index (dimensionless).tShear stress (N/m^2) and$\dot{\gamma}$The shear rate is 1/s. η_∞Low viscosity at high shear rate (infinite shear viscosity Pa s^n) is.

2-5-2- Oscillatory dynamic tests

Strain sweep test in the strain range (0.01 to 1000%, frequency 1HZ, temperature°C5 and 85) were performed to determine the linear viscoelastic region. Frequency sweep test at constant strain (3% Pascal) in the frequency range (0.1 to 100 Hz) and at constant temperature°C5 and 85 were used to evaluate the viscoelastic properties.

6-2- Statistical analysis:

All experiments will be performed in triplicate and statistical analysis will be performed using Minitab software. A completely randomized design will be used to examine the results. Data will be analyzed by analysis of variance (ANOVA) in Matlab software and differences between means will be compared using Duncan's range test at a significance level of 95%.

3- Results and discussion

1.3- Fourier transform infrared spectroscopy (FT-IR)

The FT-IR spectrum of purified plum gum (Figure 1) confirms the presence of the main functional groups of a polysaccharide hydrocolloid. The broad region (3200–3600 cm⁻¹ (peak ~3400 cm⁻¹) In this region, a broad and relatively intense band is observed, which is related to the stretching vibration of hydroxyl groups (–OH). This peak usually indicates the presence of extensive hydrogen bonds and the polysaccharide nature of the gum. Such a band has been reported in all plant gums (cayenne, locust bean, etc.). The region (1600–1650 cm⁻¹ (peak ~1608 cm⁻¹)) is related to the bending vibration of OH or C=O bonds of carboxylates (especially in acidic polysaccharides). This indicates that plum gum contains a significant amount of acidic groups or their salts (such as galacturonic acid), which are common in gums of the family.*Rosaceae*It is common. The carbohydrate fingerprint region (800–1200 cm^{-1}) is the most important region for the detection of polysaccharides. It represents the C–O–C bonds in the structure of sugar rings, the C–O stretching vibration in alcohols and polyols, and the specific patterns of the polysaccharide structure. This region is completely consistent with the structure of polysaccharide gums reported in similar studies. The FT-IR spectrum showed that plum gum is mainly composed of polysaccharides with hydroxyl, carboxylate groups, and C–O–C bonds. The presence of distinct bands in the fingerprint region confirms the polysaccharide nature and its similarity to other plant gums. Our results were consistent with those of Shi et al. (2019) [6, 7].

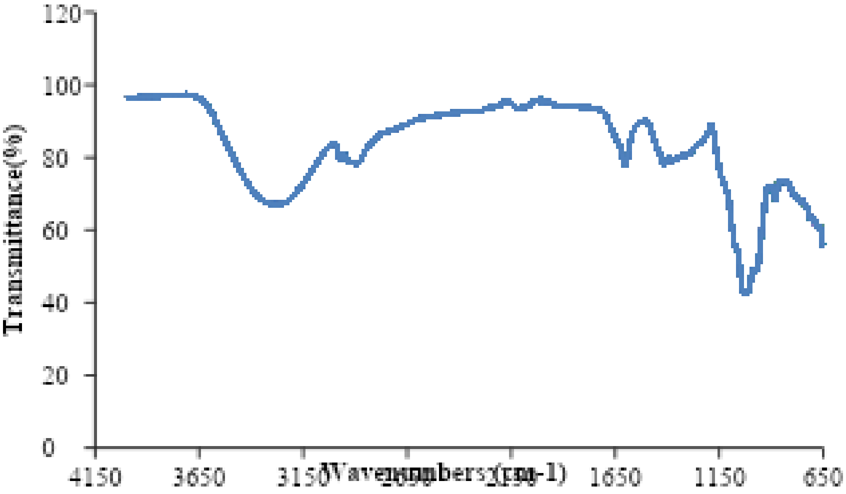

Figure 1- Fourier transform infrared spectroscopy of Alooche gum

2.3- Zeta potential

The zeta potential of crude and purified plum gum is shown in Table 1. Purified plum gum has a higher zeta potential value than crude gum. Zeta potential reflects the stability of the solution. Higher zeta potential indicates better colloidal stability due to the two-way barrier between the electrical double layers of macromolecules [8]. Because the higher surface charge increases the**Electrostatic repulsion**between particles and prevent aggregation, flocculation or sedimentation. In fact, when the zeta potential value is lower, there is not enough repulsive force to prevent macromolecules from approaching and agglomerating, and the system is subject to instability.Typically, zeta potential values**More than +30 mV**Or**Less than−30 mV**indicate proper stability of colloidal systems; while values between−The unstable or semi-stable region is considered to be between -30 and +30 mV. The increase in zeta potential in the purified gum is probably due to the removal of impurities, reduction of surface neutralizing charges, and increased uniformity of molecular structure, which ultimately improved the physical stability and dispersion of the system.[9 and 10]

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Table 1- Zeta potential of Alooche gum solutions

Sample	Zeta potential (mV)
Raw gum	-11.00±0.3^{b}
Purified gum	-14.80±0.5^{a}

3-3- Color evaluation

Colorimetry is a very important tool for gum quality control, as the color of the gum provides precise information about the degree of purity, oxidation, amount of impurities, harvesting conditions and even the drying process. Raw gum is usually darker, especially if it contains skin and plant debris, oxidation by air, sediments and decomposed sugars. If L* is high and a, b are within the standard range, the gum is purer. If L* is reduced, the gum is probably impure or oxidized. In the purification process, it is expected that L* will increase (brighten) and a* and b* values will approach the natural values of the gum. By comparing the raw and purified sample, it is possible to understand whether the purification process has been successful or not. Color is one of the most sensitive indicators of gum oxidation. Darkening (low L*) occurs with oxidation. Thermal degradation causes an abnormal increase in (a* redness) and (b* yellowness). If b* increases in the sample after heating or storage, the possibility of non-enzymatic browning is high. The color parameters of raw and purified plum gum are shown in Table 2. The brightness value obtained for the purified raw gum was 99.53, which was higher than that of the raw gum. The values obtained were higher than those obtained by Fathi et al. (a2016) and Fathi et al. (b2016) for the gums.*Cherry tree*and*Prunus armeniaca*[11, 12, 13]. Also, the yellowness decreased with purification. The yellowness value for the purified gum was 1.46.

Table 2- Color parameters of raw and purified Alooche gum powders

Sample	L*	a*	b*	WITH A
Raw gum	99.48±0.04^{a}	-0.04±0.02^{b}	1.50±0.55^{a}	1.46±0.54^{a}
Purified gum	99.53±0.19^{a}	0.04±0.02^{a}	1.46±0.14^{a}	1.47±0.14^{a}

4.3- Analysis of Steady Shear Flow Behavior

Figure 2 shows the effect of temperatures of 5°C and 85°C on the viscosity of plum gum at concentrations of 4, 6 and 8%. With increasing shear rate, the viscosity of plum gum decreases, indicating a shear-thinning behavior of the samples. This behavior is expected for polysaccharide solutions due to their polymeric structure and high molecular weight. With increasing shear rate, the random chains of polymer molecules align in the direction of flow, producing solutions with lower viscosity and causing less interaction in adjacent polymer chains. At high shear rates, the decrease in viscosity may be associated with a decrease in the number of chain entanglements [14]. Our results were consistent with those of Fathi et al. (2016a) who investigated the rheological properties, chemical structure, and molecular weight of purified cherry secretory gum [11].

According to Tables 3, 4 and 7, the Powerlaw, Herschel-Balkeley and Cisco models have R^{2}were higher than other models, indicating the suitability of these rheological models for analyzing the shear thinning characteristics of plum gum. All samples have shear thinning behavior ($n < 1$). In the Powerla, Herschel Bulkley and Cisco models, increasing the concentration causes an increase in the consistency index. However, with increasing concentration, the pseudoplastic behavior increases because n decreases. As is clear from Table 3, the highest consistency index is related to the concentration of 8% (Pa s^{n}34.65) at 5°C. Also, the lowest flow index was related to the concentration of 8% at 5°C (0.38). Our results were consistent with those of Fathi et al. (2016) [11].

With increasing temperature from 5°C to 85°C, the consistency index decreased while the flow index increased. The lowest consistency index and highest consistency flow index values were obtained for the 85°C sample at 4% concentration in the Powerla, Herschel-Balkely, and Cisco models. Our results are in agreement with Fathi et al. (2016) [12]. Also, Marcotte et al. (2001) and Karajian et al. (2009) obtained similar results for xanthan gum, carrageenan, pectin, starch, and watercress seed gum [15, 16].

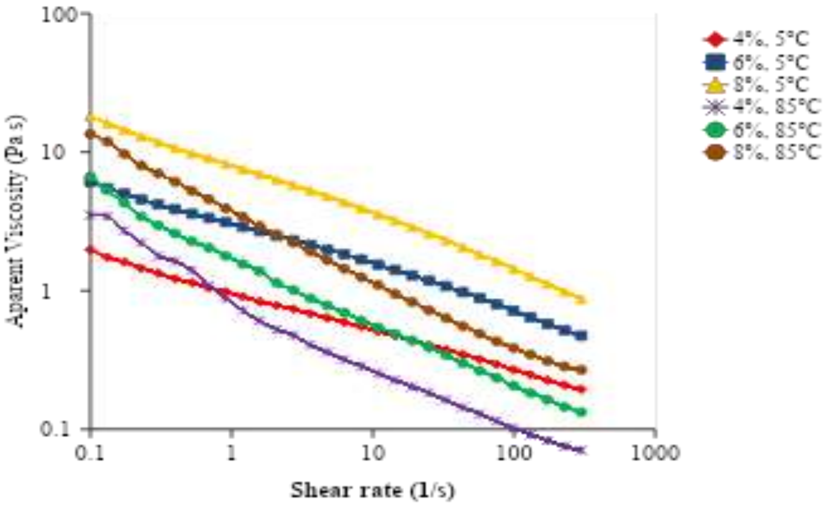

Figure 2- Effect of temperature on the viscosity of Alooche gum at different concentrations

Table 3- Effect of temperature on the rheological parameters of Power law model of Alooche gum at different concentrations

Concentration (%)	Temperature (°C)	Power Law model		
		K_p(Step^n)	n_p	R^2
4	5	3.13 ± 0.07^{c}	0.53 ± 0.00^{b}	1.00
6	5	12.60 ± 0.64^{b}	0.45 ± 0.01^{c}	1.00
8	5	34.65 ± 1.21^{a}	0.38 ± 0.00^{d}	1.00
4	85	0.74 ± 0.01^{d}	0.60 ± 0.01^{a}	1.00
6	85	2.38 ± 0.43^{c}	0.53 ± 0.04^{b}	1.00
8	85	2.68 ± 0.19^{c}	0.62 ± 0.02^{a}	1.00

Table 4- Effect of temperature on the rheological parameters of Herschel-Bulkley model of Alooche gum at different concentrations

Concentration (%)	Temperature (°C)	Herschel-Bulkley model			
		k_H (Pa×s^n)	n_H	t_{0H}(Well)	R^2
4	5	2.99 ± 0.04^{c}	0.54 ± 0.00^{b}	0.30 ± 0.07^{cd}	1.00
6	5	12.05 ± 0.46^{b}	0.45 ± 0.00^{c}	0.84 ± 0.27^{bc}	1.00
8	5	37.27 ± 1.49^{a}	0.37 ± 0.00^{d}	3.37 ± 0.18^{a}	1.00
4	85	0.64 ± 0.07^{d}	0.62 ± 0.03^{a}	0.26 ± 0.22^{cd}	1.00
6	85	2.38 ± 0.47^{cd}	0.53 ± 0.04^{b}	0.09 ± 0.20^{d}	1.00
8	85	2.32 ± 0.26^{cd}	0.64 ± 0.02^{a}	1.00 ± 0.27^{b}	1.00

Table 5- Effect of temperature on the rheological parameters of Bingham model of Alooche gum at different concentrations

		Bingham model		
Concentration (%)	Temperature (°C)	τ_{0b} (Well)	η_{β}	R^2
4	5	6.20±0.16^{c}	0.23±0.01^{d}	0.93
6	5	21.38±0.93^{b}	0.56±0.01^{b}	0.89
8	5	53.83±1.65^{a}	1.01±0.02^{a}	0.84
4	85	1.67±0.11^{d}	0.08±0.00^{f}	0.96
6	85	4.59±0.61^{c}	0.17±0.00^{and}	0.94
8	85	6.19±0.19^{c}	0.32±0.01^{c}	0.97

Table 6- Effect of temperature on the rheological parameters of Casson model of Alooche gum at different concentrations

		Casson model		
Concentration (%)	Temperature (°C)	τ_{0c} (Well)	η_{c}	R^2
4	5	12.41±0.33^{c}	0.03±0.00^{b}	0.93
6	5	43.65±1.86^{b}	0.03±0.00^{c}	0.89
8	5	107.67±3.30^{a}	0.02±0.00^{d}	0.83
4	85	3.33±0.23^{d}	0.04±0.00^{b}	0.96
6	85	9.19±1.21^{c}	0.03±0.00^{b}	0.94
8	85	12.37±0.38^{c}	0.05±0.00^{a}	0.97

Table 7- Effect of temperature on the rheological parameters of Sisko model of Alooche gum at different concentrations

		Sisko model			
Concentration (%)	Temperature (°C)	K_c (Pa×s^n)	n_c	η_{∞}	R^2
4	5	3.20±0.10^{c}	0.52±0.00^{a}	0.01±0.00^{b}	1.00
6	5	12.73±0.70^{b}	0.44±0.01^{bc}	0.01±0.01^{b}	1.00
8	5	32.19±1.02^{a}	0.42±0.00^{c}	-0.21±0.02^{c}	1.00
4	85	0.89±0.13^{cd}	0.51±0.06^{ab}	0.02±0.02^{b}	1.00
6	85	2.20±0.21^{d}	0.56±0.01^{a}	-0.03±0.04^{b}	1.00
8	85	3.09±0.02^{c}	0.54±0.02^{a}	0.09±0.03^{a}	1.00

4-4- Strain scanning

According to Figure 3, the linear region is the region where the storage modulus G’ and the loss G” are constant. While the nonlinear region starts when the moduli start to decrease. In the strain sweep test, the storage modulus G’ is constant until the strain reaches a critical point and the storage modulus starts to decrease. The critical strain indicates the deformation of the gum. Strong gum solutions have a larger linear region than weak gum solutions. In other words, the viscoelastic modulus is linear over a wider range of strain. The linear region is less for dilute solutions than for concentrated solutions, and concentrated solutions are less than for gels. While the linear region is up to 0.1% for colloidal gels and up to 1% or more for true biopolymer gels [17].

According to Table 8, with increasing concentration from 4% to 8%, storage modulus G' and loss G" increased. The highest value of G' (pa18,18) and G" (pa15,16) is related to 8% concentration at 5°C. However, with increasing temperature from 5 to 85°C, the moduli decreased. The lowest value of G' (pa2,34) and G" (pa0,41) is related to 85°C at 4% concentration. Our results were consistent with the results of Hesari Nejad et al. (2014) [17]. Loss tangent (G″/G′tan_{δ}=) is a characteristic for evaluating viscoelastic behavior. If it is smaller than 1, it indicates elastic behavior, while if it is larger than 1, it indicates viscous behavior. If the tangent is larger than 0.1, it means that the samples are not true gels and their structure is between that of a dense biopolymer and a true gel [18]. In other words, the study of the polymer system introduces a numerical range for the tangent: for dilute solutions, very high; for amorphous polymers (0.2-3); and for glassy crystalline polymers and gels (close to 0.01). According to Table 8, the tangent is between (0.17-0.83), which is less than 1 and greater than 0.1, indicating the presence of a weak elastic structure in the biopolymer gel.

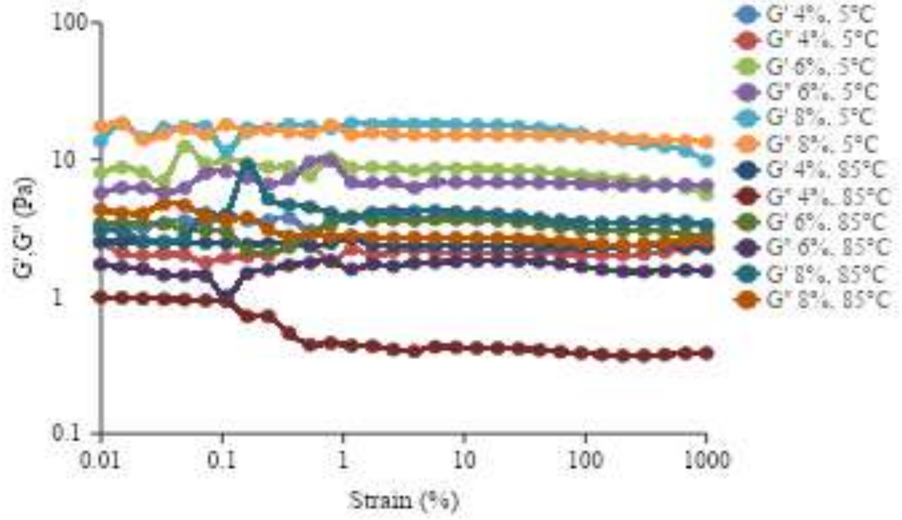

Figure 3- Storage (G′) and loss (G″) modulus performance in Strain sweep test for the effect of different Alooche gum concentrations and temperatures

Table 8- Rheological parameters of Strain sweep test (frequency 1 HZ) at different plum gum concentrations and temperatures

Concentration (%)	Temperature (°C)	$tan\ \delta$	τ **and(so)**	**G′LVE(so)**	**G″LVE(so)**	τ **and(so)**	**Gf(so)**	τ_f**(so)**
4	5	0.57±0.00^{d}	0.13±0.01^{c}	3.80±0.17^{c}	12.15±0.09^{c} d	0.13±0.01^{c}	-	-
6	5	0.77±0.01^{b}	0.33±0.02^{b}	8.56±0.56^{b}	6.62±0.47^{b}	0.33±0.02^{b}	6.51±0.12^{b}	51.46±0.76^{a}
8	5	0.83±0.01^{a}	0.71±0.01^{a}	18.18±0.39^{a}	15.16±0.17^{a}	0.71±0.01^{a}	14.44±0.10^{a}	34.43±0.52^{b}
4	85	0.17±0.01^{f}	0.07±0.00^{d}	2.34±0.03^{d}	0.41±0.01^{and}	0.07±0.00^{d}	-	-
6	85	0.47±0.02^{and}	0.12±0.01^{c}	3.63±0.27^{c}	1.70±0.019^{d}	0.12±0.01^{c}	-	-
8	85	0.65±0.03^{c}	0.15±0.00^{c}	4.18±0.10^{c}	2.70±0.06^{c}	0.15±0.00^{c}	-	-

5.4- Frequency scanning

Frequency sweep test can be used to describe or classify dispersions. Four common and traditional classifications are: dilute solution, entangled network systems (or concentrated solution), weak gel and strong gel [17]. Figure 4 shows the changes of G' and G" moduli at concentrations of 4, 6 and 8% and temperatures of 5 and 85 °C in the frequency sweep test. With increasing frequency, the G' and G" moduli are increasing. At a given frequency, the G' modulus is always larger than G". Our results are in accordance with Naji Tabasi et al. (2017) and Hesari Nejad et al. (2014) [17].

Therefore, purified secretory gum of plum behaves more like a solid; that is, deformations will be essentially elastic and recoverable. Such behavior is in good agreement with the behavior found in other hydrocolloids such as psyllium, rice starch, xanthan, basil seed. With increasing concentration from 4% to 8% at 5°C, the moduli G' and G" are increasing. According to the findings of Hesari Nejad et al. (2014), this is due to the formation of a more complex structure at higher concentrations [17]. In other words, at low concentrations, there are many intermolecular regions that cannot participate in non-covalent cross-linking. While at higher concentrations, the maximum number of binding regions is formed. On the other hand, with increasing concentration, G' becomes greater than G", indicating a clear tendency to form macromolecular networks. This type of behavior has been reported by other researchers for gellan, k-carrageenan/LBG and psyllium gels. According to Table 9, with increasing temperature from 5 to 85 °C, the values of G' and G" decreased, while at both temperatures the value of G' was always higher than G". According to Table 9, the tangent ranged from (0.32-0.89), which is less than 1 and more than 0.1, indicating the presence of a weak elastic structure in the biopolymer gel.

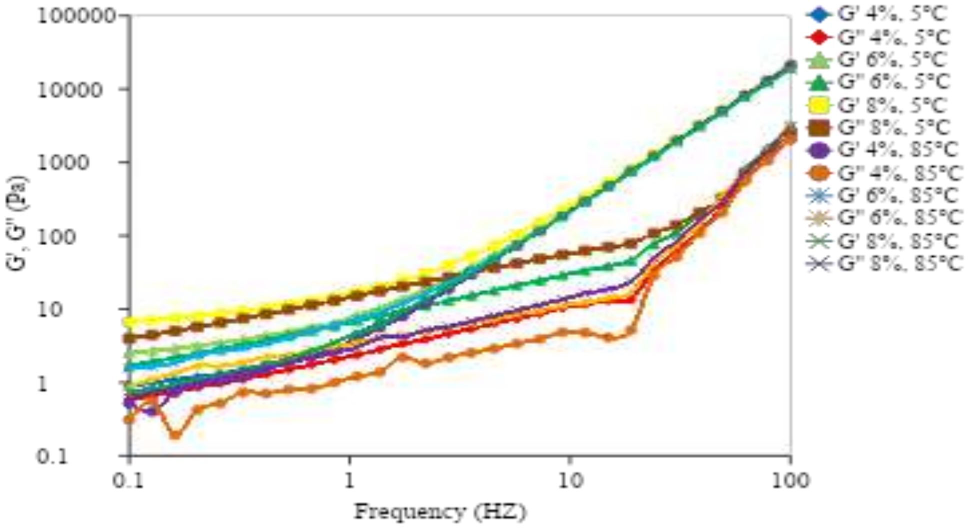

Figure 4- Storage (G′) and loss (G″) modulus performance in Frequency sweep test for the effect of different Alooche gum concentrations and temperatures

Table 9- Rheological parameters of Frequency sweep test (frequency 1 HZ) at different plum gum concentrations and temperatures

Concentration (%)	Temperature (°C)	G'_{LVE}(so)	G''_{LVE}(so)	tan_{δ}	$\eta*$ (Step)	Slope of$the*$
4	5	3.84 ± 0.38^{c}	2.3 ± 0.04^{and}	0.60 ± 0.05^{b}	0.71 ± 0.06^{of}	-0.49 ± 0.09^{bc}
6	5	7.61 ± 0.48^{b}	6.57 ± 0.24^{b}	0.86 ± 0.02^{a}	1.6 ± 0.08^{b}	-0.51 ± 0.02^{bc}
8	5	16.25 ± 0.35^{a}	14.35 ± 0.15^{a}	0.89 ± 0.01^{a}	3.45 ± 0.06^{a}	-0.56 ± 0.00^{c}
4	85	3.52 ± 0.34^{c}	1.15 ± 0.24^{f}	0.32 ± 0.04^{d}	0.59 ± 0.06^{and}	-0.24 ± 0.06^{a}
6	85	6.85 ± 0.48^{b}	3.33 ± 0.16^{c}	0.49 ± 0.01^{c}	1.21 ± 0.08^{c}	-0.38 ± 0.06^{ab}
8	85	4.24 ± 0.31^{c}	2.84 ± 0.12^{d}	0.67 ± 0.02^{b}	0.81 ± 0.05^{d}	-0.30 ± 0.03^{a}

5- Conclusion

In this study, the physicochemical and rheological properties of raw and purified plum tree exudate were investigated. According to the results obtained, the rheological properties of purified plum exudate were investigated at concentrations of 4, 6, and 8% at temperatures of 5 and 85 °C. All samples had shear thinning behavior. The Powerla, Herschel Bulkley, and Cisco models were the best models for investigating the pseudoplastic properties of plum gum. Increasing the concentration from 4 to 8% increased the consistency index (kp). While increasing the temperature from 5 to 85 °C, this index decreased. In the strain sweep test, increasing the concentration from 4 to 8% increased the storage modulus G' and the loss G" . While increasing the temperature decreased the moduli. In the frequency sweep test, the value of G' was always greater than G". With increasing concentration, G' and G" increased, while increasing temperature decreased them. In color evaluation, the purified gum had higher brightness and less yellowness.

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Authors' Contributions

All activities were carried out by the author.

Competitive interests

The author confirms that he has no financial conflicts of interest or competing interests in this study.

5- Resources

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مقاله علمی_پژوهشی

تأثیر غلظت و دما بر رئولوژی رفتار جریان و دینامیک نوسانی صمغ ترشحی خالص شده آلوچه

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چکیده

خانواده گل‌سرخیان (Rosaceae) شامل گونه‌های متعددی همچون هلو، زردآلو، آلو، گیلاس و بادام است که به دلیل تولید صمغ‌های طبیعی شناخته می‌شوند. گونه Prunus (cerasifera) آلوچه یکی از تولیدکنندگان این صمغ‌ها بوده و صمغ آن مایع، شفاف، مخاط‌گونه و به رنگ زرد روشن است. در پژوهش حاضر، ویژگی‌های رئولوژیکی صمغ خام و خالص‌سازی‌شده آلوچه در غلظت‌های ٤، ٦ و ٨ درصد و در دماهای ٥ و ٨٥ درجه سانتی‌گراد بررسی شد. آزمون‌های رفتار جریان، روبش کرنش و روبش فرکانس برای ارزیابی رفتار مکانیکی صمغ انجام گرفت. همچنین طیف‌سنجی FTIR با هدف شناسایی گروه‌های عاملی و تعیین ساختار شیمیایی نمونه‌ها، پتانسیل زتا و ارزیابی رنگی مورد بررسی قرار گرفتند. نتایج نشان داد که تمامی نمونه‌ها رفتار سودوپلاستیک (رقیق‌شونده با برش) دارند. از میان مدل‌های رئولوژیک به‌کاررفته، مدل‌های هرشل–بالکلی، پاورلا و سیسکو بهترین برازش را داشته و دارای بالاترین ضریب تعیین (R^2) بودند. افزایش غلظت از ٤ به ٨ درصد موجب افزایش مدول‌های ذخیره و افت شد، در حالی‌که افزایش دما کاهش این مدول‌ها را به دنبال داشت. یافته‌های FTIR نیز وجود گروه‌های عاملی مرتبط با کربوهیدرات‌ها و ساختار اصلی صمغ آلوچه را در ناحیه اثرانگشتی تأیید کرد.