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RHEOLOGICAL AND SENSORIAL PROPERTIES OF SESAME PASTE BLENDS PREPARED WITH DIFFERENT SUGAR SOURCES

Dilara Tomruk[1], Esra Devseren[1], Işıl İlter[1], Saniye Akyıl[1], Mehmet Koç[2*], Figen Kaymak Ertekin[1]
[1]Department of Food Engineering, Faculty of Engineering, Ege University, Izmir, Turkey.
[2]Department of Food Engineering, Faculty of Engineering, Adnan Menderes University, Aydın, Turkey.

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ABSTRACT
Rheological properties of sesame paste (SP) blends, which were prepared with concentrated grape juice (CGJ), honey and sugar syrup were determined using rotational viscometer at different SP concentrations (40, 50 and 60%) and temperatures (25, 35, 40, 50°C). Flow behavior of the SP/CGJ blends were expressed by Power law model, however SP/honey and SP/sugar syrup blends were fitted to the Bingham Plastic model. The relationship of the consistency index "K" and SP concentration was described by exponential and power functions. Rising in temperature lead to a decrease in the consistency index of SP blends. Increasing in SP concentration resulted in an increase in consistency index of samples. Sensorial analysis was evaluated to research the effect of SP concentration and type of sugar sources on sensorial properties. Spreadibility and mouth-coating properties of blends enhanced with the increase in SP concentration. Moreover rheological properties highly correlated with sensorial properties of samples.
Keywords: Sesame paste, rheological properties, honey, sugar syrup, concentrated grape juice

FARKLI ŞEKER KAYNAKLARI İLE HAZIRLANAN TAHİN KARIŞIMLARININ REOLOJİK VE DUYUSAL ÖZELLİKLERİ

ÖZ
Farklı tahin konsantrasyonlarında (%40, 50 ve 60) ve farklı sıcaklıklarda (25, 35, 40, 50°C) pekmez, bal ve şeker şurubu kullanılarak hazırlanan tahin karışımlarının reolojik özellikleri belirlenmiştir. Tahin/pekmez karışımı için akış davranışı Power modeli ile ifade edilmiştir, ancak tahin/bal ve tahin/ şeker şurubu karışımı için Bingham Plastik modeline uymuştur. Kıvam indeksi "K" ile tahin konsantrasyonu arasındaki ilişki üstel ve power fonksiyonlarıyla tanımlanmıştır. Sıcaklığın yükselmesiyle birlikte kıvam indeksi azalmıştır. Fakat tahin konsantrasyonun artışıyla birlikte örneklerin kıvam indeksi yükselmiştir. Duyusal analiz, tahin konsantrasyonunun ve tatlandırıcı çeşidinin karışımların üzerindeki etkisini araştırmak için değerlendirilmiştir. Karışımların sürülebilirlik ve ağzın kaplanması özellikleri tahin konsantrasyonun yükselmesiyle birlikte iyileşmiştir. Ayrıca tahin karışımlarının reolojik özellikleri, örneklerin duyusal özellikleri ile oldukça yüksek bir korelasyona sahiptir.
Anahtar kelimeler: Tahin, reolojik özellikler, bal, şeker şurubu, pekmez

* *Corresponding author* / Yazışmalardan sorumlu yazar;
✉ mehmetkoc@adu.edu.tr, ✆ (+90) 256 213 7503 🖷 (+90) 256 213 6686

INTRODUCTION

Sesame paste (SP) is one of popular traditional products in East Asian and Middle Eastern countries (Johnson et al., 1977; Sawaya et al., 1985), also in Turkey. Roasted, dehulled or hulled and ground sesame seeds are used for SP production. SP is rich of lipids, proteins and dietary fiber (Abu-Jdayil et al., 2002). India, Sudan, China and Burma (Abou-Gharbia et al., 1997) are the main countries cultivating sesame seeds (*Sesamum indicum* L.). Sesame has also been considerably used as an ingredient (bakery product) or consumed directly as seed, oil or paste for many years.

SP is generally consumed after mixing with different sugar sources. Honey, sugar syrup, date syrup and concentrated grape juice (CGJ) (Kaya, 2002) are used for this purpose. However SP and these sugar sources are separately available for sale in the market and the SP blend is prepared by consumers themselves in accordance with their preference. Ready-mixed SP/sugar source blend would be an innovative and value-added product for the food market. One of the main criteria that affects the consumers' acceptance is the spreadibility of the SP blends. Spreadibility is a property that is highly related with the consistency of the blends (Alpaslan & Hayta, 2002). The consistency known as one of rheological properties of food materials determines the shelf-life stability of final product (Abu-Jdayil et al., 2002).

SP blends which are an emulsion, consists of dispersed phase (oil phase) as SP and continuous phase (water phase) as sugar sources. Emulsion is formed due to interaction of proteins and lipids in the SP blends (Alpaslan & Hayta, 2002). In the emulsion, sesame proteins which act as emulsifier are very important at oil-water interface. The rheological properties of an emulsion are directly affected by temperature and concentration of oil and water phase (Rao, 1999). As mentioned above, interaction between the lipids and the proteins leads to formation of emulsion which also improves the sensorial attributes like mouthfeel of the product.

In literature many studies have been published that are related with the rheological properties of sesame paste. It has been reported that pseudoplastic and thixotropic behavior reflects the steady shear behavior of sesame paste (Alpaslan & Hayta, 2002; Abu-Jdayil et al., 2002; Altay & Ak, 2005). Alpaslan and Hayta (2005), have also studied the rheological and sensorial quality of CGJ and SP blends at different concentrations and temperatures. It was determined that flow behavior and consistency index is influenced by the CGJ content and temperature. As the CGJ content increased, emulsion stability of the blends has improved. Non-Newtonian behavior has successfully explained the flow behavior of CGJ (Kaya, 2002; Sengul et al., 2005). Besides, CGJ and SP blends exhibited non-Newtonian pseudoplastic behavior. Arslan and co-workers (2005); were also determined the rheological behavior of SP and CGJ blends at different SP concentrations and temperatures. But they found that SP/CGJ blends showed non-Newtonian, shear thinning behavior at different temperatures. The flow behavior of blends was successfully explained with the power-law model. Temperature has significantly affected the flow behavior index, "n" and the consistency coefficient, "K" parameters. As mentioned above, CGJ is not only way to produce SP blend. Thus, Gharehyakheh and co-workers (2014); prepared SP blend with honey and studied its rheological properties. Result of this study revealed that honey and SP blend showed time independency and shear thinning behavior.
The objectives of this study were to prepare SP blends with CGJ, honey and sugar syrup with different SP concentration and determine the flow behavior of these blends at different temperatures.

MATERIALS AND METHOD

Materials

SP (1.18 % moisture, 50.76 % oil, 22.85 % carbohydrate, 23.35 % protein, 1.86 % ash), CGJ, pine honey (in this context it is called honey) and sugar (sucrose) were obtained by local market. All raw materials were kept at room temperature in dark condition until they were used. The brix values of CGJ and honey were 69 and 78°Brix, respectively.

Preparation of SP/sugar rich product blends

In order to get standard total soluble solid content of sugar sources, CGJ and honey were diluted with tapped water to 65°Brix. Sugar syrup was prepared with sugar and tapped water and its brix was also adjusted to 65°Brix. 100 g of blends were prepared by adding SP to sugar sources at different SP concentrations of 40, 50 and 60 % (w/w) and mixing gently with a spatula for a minute.

Rheological measurements

Rheological measurements of the SP/CGJ (SP-C), SP/sugar syrup (SP-S) and SP/honey (SP-H) blends were conducted using a rotational viscometer (Fungilab, Spain) equipped with the small sample adapter and TR 8, 9, 10 or 11 spindles. Spindle type was chosen depending on blends' concentration. Also, the adapter includes a thermocouple which is connected to viscometer on the bottom to measure the temperature of the samples. In order to keep the temperature at constant levels during the measurements, a chiller (Daihan, South Korea) was connected to the jacket surrounding the sample adapter cell. The rheological measurements were carried out at different temperatures 25, 35, 40 and 50 °C. After the sample was poured to the sample cell, it was allowed to stand for 10 min in the jacket to reach the targeted measuring temperature without working of viscometer. Then the viscometer ran at a wide rotor speed range (0.1-200 rpm) for 5 minutes. The rheological data including apparent viscosity, shear stress, shear rate, torque % and temperature were recorded for each measurement and transferred to Microsoft Excel by Datalogger software (Fungilab, Spain).

Each experiments were carried out in two replicates.

The experimental data were fitted to various models (Eq. 1-4) to obtain rheological (τ_0, μ, K and n) and statistical (R^2) parameters;

Newtonian Model	$\tau=\mu*\gamma$	[1]
Power Law Model	$\tau=K*\gamma^n$	[2]
Herschel Bulkley Model	$\tau= \tau_0+ K*\gamma^n$	[3]
Bingham Plastic Models	$\tau= \tau_0+ K*\gamma$	[4]

Where τ is shear stress (Pa), γ is shear rate (1/s), *n* is flow behaviour index (dimensionless), *K* is consistency coefficient, ($Pa*s^n$),μ is viscosity (Pa*s) and τ_0 is yield stress (Pa).

Sensory Evaluation

Sensory analysis of SP blends with CGJ, honey, sugar syrup was performed according to Alpaslan and Hayta (2002), with 10 panelists aged 22 to 30. All panelists were non-smokers. A slice of white bread and a knife for each blend were given all panelists. The intensity was determined using a 5-point scale (1 being the lowest and 5 the highest). Panelists also evaluated the general acceptance, appearance, color, smell, mouth-coating, spreadibility and taste of the blends.

Statistical Analysis

The statistical analyses were carried out by using the SPSS version 15.0 Windows software program (SPSS Inc., Chicago, IL). The results were evaluated by analysis of variance (ANOVA) test. The mean comparison was performed with Duncan's multiple range test at $P<0.05$ level. Pearson correlation test also carried out to determine the rheological and sensorial properties relationship.

RESULTS AND DISCUSSION

The rheological properties of SP blends, which were prepared with CGJ, sugar syrup and honey and consisted of different SP concentrations (40, 50, 60%, w/w), were determined with respect to temperature at 25, 35, 40 and 50°C. The results of apparent viscosity of SP blends changing with shear rate showed that the flow behavior of all SP blends at any concentration of SP and temperature explained with non-Newtonian flow behavior. However, while the flow behavior of SP-C blends was explained with power law model, the flow behavior of SP-S and SP-H blends were successfully described with the Bingham Plastic model for all temperatures and concentrations.

Increasing in shear rate resulted in decreasing in apparent viscosity of all samples as shown in Figure 1. The flow behavior index (n) and consistency (K) values of SP-C blends were obtained by fitting the shear rate versus shear stress data to a power law model. Differences in shear rate range of the graphs was based on the selection of the appropriate range for each concentration and temperature that viscometer was able to measure properly. The values of flow behavior index, n, were ranged from 0.119 to 0.896, while the consistency index, K, was ranged from 0.265 to 7.338Pa.s (Table 1). A decrease in the SP concentration in SP-C blends leads to an increase in viscosity of blends for all temperatures whereas the consistency decreased with rising temperature. The rheograms of SP-S and SP-H blends with different SP concentrations at different temperatures were also given in Figure 1. Apparent viscosity of these blends decreased with increasing shear rate indicating the shear thinning behavior similar to SP-C blends. The consistency index (K) values and yield stress (τ_0) of these blends were determined with fitting the shear rate versus shear stress data to a Bingham Plastic model. Model parameters for SP-S and SP-H blends were given in Table 1. The values of consistency index (K) were of SP-S blends were ranged from 0.049 to 0.480 Pa·s^n and the yield stress (τ_0) were ranged between 0.581 and 14.00 Pa. The R^2 values were ranged from 0.924 to 1.000 for all SP-S blends. Moreover, indicating the results for SP-H blends the values of consistency index (K) were ranged from 0.040 to 0.594Pa·s and the yield stress (τ_0) were ranged between 0.485 and 8.99 Pa. The R^2 values were ranged from 0.898 to 1.000 at all concentrations and temperatures.

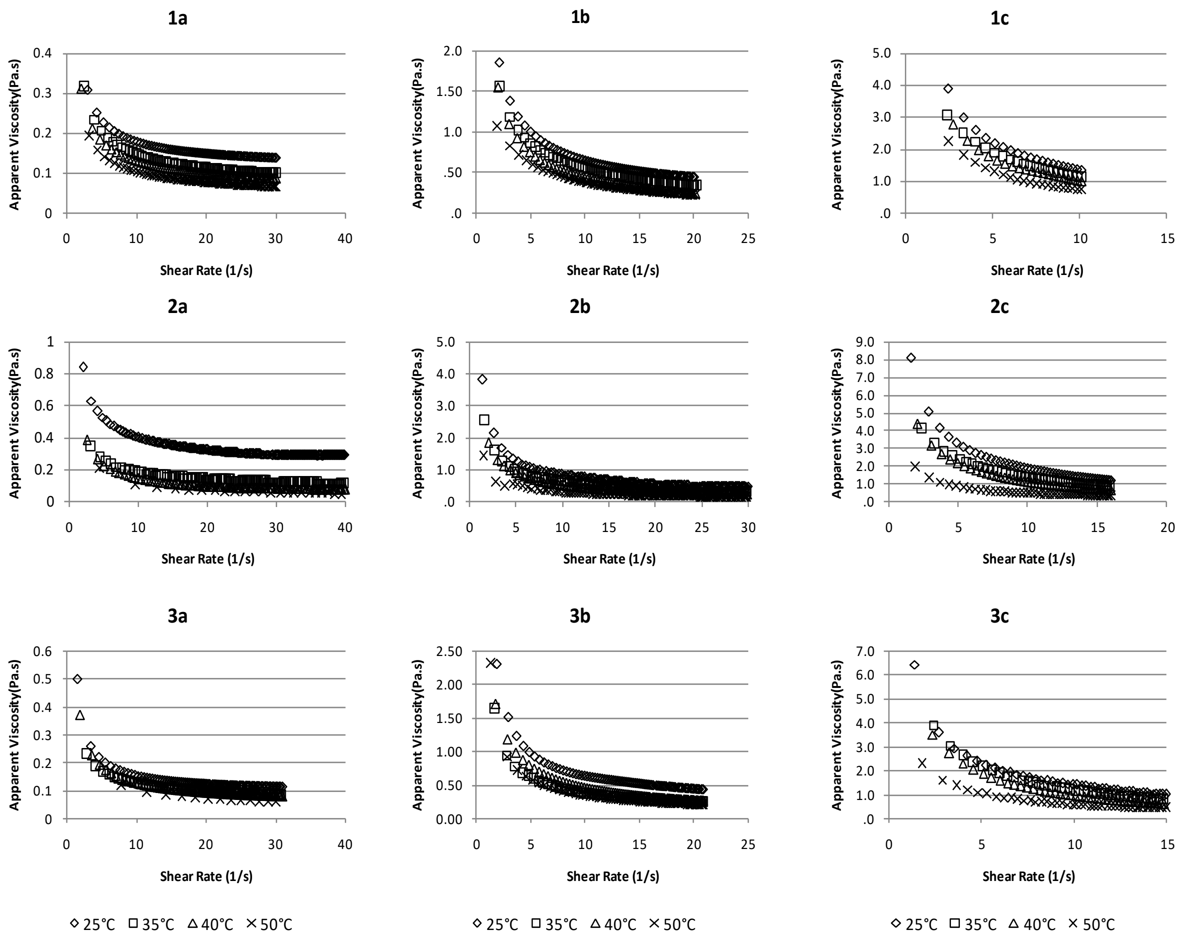

Figure 1. Apparent viscosity and shear rate relationship for SP blends. Numbers 1, 2, 3 represent SP-C, SP-S and SP-H blends, respectively. a, b, c letters represent containing 40%, 50% and 60% SP at different temperatures, respectively

High SP concentration caused a viscous SP blends at all temperature while the consistency index of blends decreased. Maskan and Göğüş (2000), explained this circumstance as molecular movements and interfacial film formation due to high solid content. However the apparent viscosity of SP blends decreased with increasing shear rate. Rao (1999), showed that generating hydrodynamic forces and increasing in interaction of sugar, oil and protein lead to the structural deformation of the food blend. Singh and co-workers (2003); also explained that shearing resulted in deformation and disruption of oil droplets. Moros and co-workers (2002); reported that egg-yolk stabilized emulsions induced shear structural breakdown. It's because of oil droplet deflocculation.

Table 1. Flow behavior parameters for SP/sugar syrup (SP-S), SP/honey (SP-H) and SP/CGJ (SP-C) blends at different concentrations and temperatures

Samples	Temperature (°C)	SP Concentration								
		40%			50%			60%		
		K ($Pa.s^n$)	τ_0 (Pa)	R^2	K ($Pa.s^n$)	τ_0 (Pa)	R^2	K ($Pa.s^n$)	τ_0 (Pa)	R^2
SP-S*	25	0.114^{a}	0.848^{a}	1.000	0.319^{a}	4.89^{a}	0.989	0.480^{a}	14.00^{a}	0.924
	35	0.069^{a}	0.747^{a}	0.999	0.157^{a}	4.64^{a}	0.960	0.364^{a}	9.88^{b}	0.927
	40	0.058^{a}	0.637^{a}	0.997	0.109^{a}	3.93^{a}	0.988	0.225^{ab}	8.64^{b}	0.966
	50	0.049^{a}	0.581^{a}	0.994	0.072^{a}	2.15^{a}	0.987	0.095^{b}	4.13^{c}	0.941
SP-H*	25	0.094^{a}	0.485^{a}	0.999	0.266^{a}	3.63^{a}	0.993	0.594^{a}	8.44^{a}	0.986
	35	0.069^{ab}	0.822^{a}	0.999	0.202^{a}	2.15^{a}	0.989	0.353^{ab}	8.99^{a}	0.921
	40	0.051^{b}	0.729^{a}	1.000	0.147^{a}	3.29^{a}	0.962	0.237^{ab}	8.19^{a}	0.909
	50	0.040^{b}	0.667^{a}	0.998	0.071^{a}	2.66^{a}	0.987	0.153^{b}	4.65^{b}	0.898
		K ($Pa.s^n$)	n	R^2	K ($Pa.s^n$)	n	R^2	K ($Pa.s^n$)	n	R^2
SP-C**	25	0.347^{a}	0.896	0.988	2.540^{a}	0.410	0.995	7.338^{a}	0.266	0.993
	35	0.313^{a}	0.692	0.996	2.101^{a}	0.333	0.997	5.996^{ab}	0.289	0.987
	40	0.280^{a}	0.661	0.996	1.881^{a}	0.370	0.994	5.634^{ab}	0.119	0.917
	50	0.265^{a}	0.638	0.993	1.610^{a}	0.338	0.962	4.179^{b}	0.326	0.981

* Flow behavior described with Bingham Plastic model
** Flow behavior described with power law model
The different letter in the same column are significantly different ($p<0.05$).

Rising in temperature lead to a decrease in the consistency index of SP blends. Içier (2009), discovered that the consistency index of whey solutions increased as the temperature decreased. Marcotte and co-workers (2001); and Abu-Jdayil and co-workers (2002); also found that the consistency coefficients changed inversely with temperature. Heating could break molecular complexity and bonds could stabilize the molecular structure and reduce the effective molecular volume in protein and sugars resulting in a decrease in viscosity (Alpaslan & Hayta 2002). SP is mainly composed of oil and protein while CGJ, honey and sugar syrup are rich in sugar. The viscosity of SP blends containing different sugar sources may also be controlled by the molecular weight of sugars in these sugar sources.

Effect of Temperature and SP Concentration on Activation Energy

Arrhenius-type equation successfully describes relation of temperature and consistency coefficient as,

$$K = K_t . e^{-\frac{E_a}{RT}} \qquad [5]$$

where, K_t are the experimental constant, E_a is the activation energy (kJ/mol), R is the universal gas constant (J/mol·K), and T is the absolute temperature (K). Before process can occur, E_a as a kind of energy barrier must be overcame (Rao 1999). Linear regression analysis was performed to the logarithmic form of Eq. (5) for establish relationship between the parameters (Table 2).

Table 2. Parameters of the Arrhenius equation (Eq.5) for temperature dependency of consistency coefficient at different SP concentration

Samples	SP Concentration (%)	K_t (mPa·s)	E_a (kJ/mol)	R^2
SP-C	40	9.34	8.94	0.953
	50	6.65	14.72	0.997
	60	6.07	17.64	0.971
SP-S	40	1.82×10^{-3}	27.18	0.946
	50	1.09×10^{-6}	48.17	0.987
	60	3.66×10^{-7}	52.43	0.921
SP-H	40	1.11×10^{-3}	28.11	0.982
	50	3.55×10^{-5}	39.47	0.947
	60	1.06×10^{-5}	44.20	0.992

E_a explained how temperature effected the viscosity of the blends. The results showed that increasing in SP concentration resulted in an increase in E_a while a decrease in experimental constant K_t. Alpaslan and Hayta (2002) also observed that E_a values of SP and CGJ blends decreased with increasing CGJ concentration.

In most of food products, the composition of ingredients directly affected the rheological properties of products. The viscosity of food products inversely correlated with solid concentration (Bourne, 2002) at constant temperature. Rao (1999), described the consistency index, K, as a function of SP concentration (C) with exponential (Eq. 6) and power (Eq. 7) models

$$K = K_{c_1} e^{a_1 C} \qquad [6]$$

$$K = K_{c_2} C^{a_2} \qquad [7]$$

where, K_{c1} , K_{c2}, a_1, and a_2 are experimental constants (Rao 1999).The corresponding model parameters were shown in Table 1. The effect of SP concentration on the consistency coefficient was defined sufficiently with both models. Effect of SP-C, SP-S and SP-H concentrations on the consistency coefficient were given in Table 3 for different temperatures.

Table 3. Effect of SP concentration on the consistency coefficient of samples at different temperatures

Samples	Temperature (°C)	Exponential Model (Eq. 6)			Power Model (Eq. 7)		
		a_1	K_{c1}	R^2	a_2	K_{c2}	R^2
SP-C	25	0.152	0.907	0.970	1.045	0.125	0.972
	35	0.147	0.984	0.972	1.032	0.129	0.975
	40	0.150	0.791	0.976	1.062	0.113	0.978
	50	0.137	1.234	0.969	0.999	0.142	0.972
SP-S	25	0.061	13.04	0.964	0.550	0.655	0.975
	35	0.083	2.464	1.000	0.816	0.207	0.999
	40	0.067	3.876	0.998	0.703	0.301	0.996
	50	0.033	13.29	0.991	0.388	0.929	0.996
SP-H	25	0.092	2.449	0.994	0.843	0.203	0.996
	35	0.081	2.874	0.967	0.811	0.214	0.974
	40	0.076	2.663	0.955	0.810	0.196	0.964
	50	0.067	2.731	1.000	0.764	0.219	0.999

Formation of oil droplet can be asserted to increase the consistency coefficient values owing to the viscosity of the emulsion by rising SP concentration. Arslan and co-workers (2005); explained this circumstance as following, while SP content increased, a greater number of oil drops was suspended and tend to clump to form clusters. Therefore, these clusters dissolved fluids and caused to require more effort for the same flow rate. Moreover, the higher viscosity of blends could be explained that the particle-particle interactions and molecular motions also increased with solid content in terms of SP concentration (Alpaslan & Hayta 2002; Toğrul & Arslan 2004). Both exponential and power functions was used to fit the variation of E_a with SP concentration (Table 2),

$$E_a = A_1 e^{b_1 C} \quad [8]$$

$$E_a = A_2 C^{b_2} \quad [9]$$

where, A_1, A_2, b_1, and b_2, are the proportionality constants.

In order to calculate the model constants, the linearized forms of these two equations were used, as shown in Table 4. Kaya and Belibağlı (2002), stated that activation energy for a flow changes depended on the soluble solid content for a constant temperature. The dependency of E_a on the SP concentration was better described by the power model.

Table 4. Effect of SP concentration on activation energy, E_a of different samples

Samples	Exponential Model (Eq.8)			Power Model (Eq.9)		
	A_1	b_1	R^2	A_2	b_2	R^2
SP-C	2435.54	0.034	0.932	4.706	0.179	0.955
SP-S	7963.89	0.032	0.844	5.753	0.157	0.882
SP-H	11871.84	0.022	0.923	6.892	0.108	0.949

Sensory Evaluation

Sensory properties such as appearance, aroma, flavor, and texture are critical factors affecting consumer decision to buy or consume a food product (Chambers & Bowers 1993). The results of sensory analysis showed that mouth-coating, spreadibility and overall acceptance scores of blends increased with increasing of SP concentration for all samples. However the sensorial properties of the blends were evaluated with respect to appearance and color, the highest scores of these criteria were generally obtained from the blends containing 50% SP. Although the smell scores of SP blends were not significantly changed with SP concentration, increasing in SP concentration improved the taste scores of all the blends. According to the overall acceptability, the most appreciated samples were products had higher SP content than 50% irregardless of sugar sources (Table 5).

Table 5. Sensory evaluation scores of SP blends

Samples	SP Conc. (%)	Appearance	Colour	Smell	Mouth-coating	Spreadibility	Taste	Overall acceptance
SP-C	40	$3.31^{a} \pm 0.46$	$3.25^{a} \pm 0.21$	$3.75^{a} \pm 0.29$	$2.88^{a} \pm 0.39$	$2.63^{a} \pm 0.48$	$3.44^{a} \pm 0.33$	$3.00^{a} \pm 0.11$
	50	$4.00^{ab} \pm 0.16$	$4.00^{ab} \pm 0.76$	$3.94^{a} \pm 0.56$	$4.06^{b} \pm 0.56$	$3.56^{b} \pm 0.25$	$4.00^{a} \pm 0.43$	$3.88^{b} \pm 0.30$
	60	$4.25^{b} \pm 0.36$	$3.81^{b} \pm 0.53$	$4.13^{a} \pm 0.64$	$4.75^{b} \pm 0.46$	$4.69^{c} \pm 0.46$	$4.25^{a} \pm 0.21$	$4.25^{b} \pm 0.65$
SP-S	40	$3.13^{a} \pm 0.49$	$3.44^{a} \pm 0.12$	$3.44^{a} \pm 0.12$	$2.63^{a} \pm 0.22$	$2.13^{a} \pm 0.64$	$2.50^{a} \pm 0.26$	$2.68^{a} \pm 0.28$
	50	$4.00^{a} \pm 0.56$	$3.94^{a} \pm 0.26$	$4.06^{a} \pm 0.42$	$3.88^{b} \pm 0.63$	$3.75^{b} \pm 0.11$	$3.56^{b} \pm 0.23$	$3.88^{b} \pm 0.19$
	60	$3.81^{a} \pm 0.35$	$3.63^{a} \pm 0.58$	$4.13^{a} \pm 0.39$	$4.63^{b} \pm 0.44$	$4.56^{c} \pm 0.23$	$4.56^{c} \pm 0.43$	$4.38^{b} \pm 0.29$
SP-H	40	$3.50^{a} \pm 0.21$	$3.69^{a} \pm 0.40$	$3.75^{a} \pm 0.41$	$3.19^{a} \pm 0.75$	$2.38^{a} \pm 0.14$	$3.50^{a} \pm 0.53$	$3.13^{a} \pm 0.54$
	50	$4.19^{ab} \pm 0.65$	$4.31^{a} \pm 0.59$	$3.94^{a} \pm 0.16$	$3.94^{b} \pm 0.26$	$4.13^{b} \pm 0.58$	$4.19^{b} \pm 0.65$	$3.94^{b} \pm 0.43$
	60	$3.94^{b} \pm 0.42$	$3.88^{a} \pm 0.33$	$3.88^{a} \pm 0.39$	$4.50^{b} \pm 0.46$	$4.75^{b} \pm 0.46$	$4.31^{b} \pm 0.46$	$4.31^{b} \pm 0.36$

Different letters in the same column for each type of blend are significantly different ($P<0.05$).

Spreadibility and mouth-coating were significant sensorial properties of semi-solid food texture. Spreadibility exhibits the uniform distribution of the product over a surface (Shakerardekani et al., 2013). For all the blends, it was determined that spreadibility property enhanced with the increase in SP concentration and that led to highest scores given by panelists. In contrast to Alpaslan and Hayta (2002), the spreadibility of SP blends improved with increasing SP concentration. It can be clearly seen that the sensorial spreadibility scores of the SP blends increased with increasing in consistency index. The mouth-coating scores of blends also enhanced with increasing in SP concentration likewise spreadibility. Muego and Resurreccion (1993), had also reported that peanut paste samples with lower consistency exhibit less mouth-coating properties. The blends prepared with CGJ had higher mouth-coating scores compared to those prepared with sugar syrup and honey.

The correlation between rheological and sensorial properties of SP blends were given in Table 6. The results of Pearson correlation test showed that rheological properties E_a and K_t highly correlated with sensorial properties of SP blends.

Table 6. Pearson correlation (r) matrix between sensorial and rheological properties

Samples	Parameters	Appearance	Colour	Smell	Mouth-coating	Spreadibility	Taste	OA**	K_t (mPa·s)
SP-C	Colour	0.875							
	Smell	0.965	0.718						
	Mouth-coating	0.994	0.814	0.989					
	Spreadibility	0.949	0.678	0.998*	0.979				
	Taste	0.999*	0.851	0.976	0.998*	0.963			
	OA**	0.999*	0.859	0.973	0.997	0.959	0.999*		
	K_t (mPa·s)	-0.996	-0.916	-0.937	-0.979	-0.916	-0.999	-0.992	
	E_a (kJ/mol)	0.997*	0.835	0.982	0.999*	0.970	0.999*	0.999*	-0.986
SP-S	Colour	0.900							
	Smell	0.955	0.729						
	Mouth-coating	0.831	0.505	0.959					
	Spreadibility	0.856	0.545	0.971	0.999*				
	Taste	0.754	0.392	0.915	0.992	0.985			
	OA**	0.878	0.580	0.98	0.996	0.999*	0.977		
	K_t (mPa·s)	-0.978	-0.789	-0.996	-0.929	-0.945	-0.874	-0.958	
	E_a (kJ/mol)	0.933	0.683	0.998*	0.975	0.985	0.940	0.991	-0.988
SP-H	Colour	0.930							
	Smell	0.998*	0.909						
	Mouth-coating	0.692	0.378	0.729					
	Spreadibility	0.813	0.542	0.842	0.983				
	Taste	0.876	0.636	0.9	0.955	0.993			
	OA**	0.779	0.493	0.811	0.992	0.998*	0.985		
	K_t (mPa·s)	-0.927	-0.723	-0.945	-0.913	-0.972	-0.993	-0.958	
	E_a (kJ/mol)	0.792	0.512	0.823	0.989	0.999*	0.988	0.999*	-0.964

*Correlation is significant at the 0.05 level
**Overall acceptance

CONCLUSION

In this study, rheological and sensorial properties of SP blends prepared with CGJ, honey and sugar syrup and the effect of temperature and SP concentration in the blends were investigated. It was found that all the blends exhibited non-Newtonian, shear thinning fluid behavior by reason of crystal structure keeping the pasty form of SP. Flow behavior of SP-C blends was well presented by the Power law model although the flow behavior of the SP-S and SP-H blends were fitted to Bingham Plastic model for all temperatures. Both power and exponential models adequately explained the relationship between SP concentration and consistency coefficient. The activation energy values increased with increasing SP concentration in the blends. The effect of rheological properties of the SP blends on consumer preferences was demonstrated with sensorial analysis. Sensorial scores of the blends were improved with increasing SP concentration. Therefore the highest overall acceptance was obtained from the blends containing 60% SP.

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