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An analysis of the rheological properties of carob molasses- and carob powder-added peanut butter

Emine Tanrikulu[1], Adnan Bozdogan[1]*, Gokhan Durmaz[2]

[1]Department of Food Engineering, Osmaniye Korkut Ata University, 80000, Osmaniye/Turkey
[2]Department of Food Engineering, Inonu University, 44280, Malatya/Turkey
*Correspondence;
Phone: +90–328 827 10 00/3666;
Fax: +90–328–825 00 97
Adnan Bozdoğan
E-mail adress: bozdogan@osmaniye.edu.tr

ORCID No: 0000-0002-3612-5898

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Abstract

This study aimed to analyse the effects of using carob molasses (2.5%, 5%, 10%, and 20%) and carob powder (2.5%, 5%, 10%, and 20%) at different ratios on rheological of peanut butter. The examined peanut butter samples showed non-Newtonian pseudoplastic flow behaviour. The rheological properties of the peanut butter samples were found to fit the Herschel-Bulkley model, and R^2 values appeared to range between 0.9753 an 0.9988. The viscosity, yield stress (τ_0), and flow index (n) turned out to decrease along with the addition of carob molasses or carob powder to the peanut butter samples to increase the concentration, improving its viscosity and spreadability.

Keywords: *Peanut butter, Carob molasses, Carob powder, Rheology*

1.INTRODUCTION

Peanut *(Arachis hypogaea)* is an annual oil seed from the legume family growing in summer. (Tai and Young, 1975; Gaydou et al., 1983; Grosso and Guzman, 1995; Grosso et al., 1997). Peanut is mostly grown in Osmaniye and Adana in Turkey. In fact, the most important agricultural product of Osmaniye is peanut. Peanut is an essential source of protein and fat for human nutrition. Most peanuts are often consumed as nuts, while the rest is used for making peanut oil, peanut butter, cake, and chocolate, etc. (Bozdogan et al., 2017, Şahin et al., 2022).

Peanut butter is a viscous spreadable product obtained by roasting, peeling and then grinding raw peanut kernels. The grinding process breaks the cellular texture of peanut and causes its particles to become spreadable like paste, and makes its oil available. This product is also commonly referred to as peanut 'paste'. Other ingredients such as stabilizers, emulsifiers, sweeteners, and salt can also be added into peanut butter (Hepsağ, 2018). Peanut butter is a nutritious food in terms of its rich composition. It is necessary to improve the composition, quality, and functional aspects of peanut butter in order to increase its consumption. Carob is one of the oldest plants on earth. Carob tree, also known as the locust bean tree, is an evergreen tree that belongs to the legume family and grows very easily in regions where the Mediterranean climate prevails. The fruits bearing the same name as the tree have been in demand for centuries because they are both healing and delicious (Tunalıoğlu and Özkaya, 2003). Carob fruit is rich in insoluble pulp and phenolic compounds, which is why it has positive effects on human health. The studies conducted on pulp-rich foods prepared by using carob fruit or powder have revealed a considerable decrease in the total blood cholesterol and LDL levels (Zunft et al., 2003). In recent years, fried carob chips made from carob fruit have been used in Turkey as a substitute for chocolate, especially in bakery, pastry, and confectionery products as well as low-energy snacks, or they are grinded into powder, which is then mixed into food products, such as milk, to use as an alternative to cocoa (Demirtaş, 2007).

In Turkey, molasses has been produced by traditional methods from apples, grapes, mulberries and carob fruit for many years. The carob fruit, which cannot be pressed in its natural state, is extracted with water, and the extract is concentrated directly and processed into molasses (Batu, 2005). On the other hand, the product obtained by grinding carob directly into powder is called carob powder or carob flour, which is used as an additive in food production.

It is necessary to determine the rheological properties of peanut butter in terms of its texture, consistency, and quality. Rheology is the science that studies the deformation and flow of substances. The mechanical properties that cause deformation and flow on a material are also called rheological properties. In the food industry, the rheological properties of foods are important for the design of equipment such as pipelines, pumps, extruders, mixers, coating machines, heat exchangers, and homogenizers or processes related to such kinds of equipment (Rao et al. 1984; Davulcu, 2012; Bozdogan, 2017).

The current study was conducted to examine the effect of using carob molasses and carob powder in peanut butter production on the rheological properties of peanut butter.

2. MATERIALS AND METHODS

2.1. Materials

The shelled peanuts used in the production of peanut butter were purchased from a peanut wholesaler in Osmaniye province. Carob molasses (CM) and carob powder (CP) were collected from Şitoğlu Food Ind. and Trade Limited Co. (Malatya). Refined peanut oil (Oilo brand) and salt were purchased from a supermarket in Osmaniye. A food processor (Arcelik, Turkey) was used for making peanut butter.

Peanut butter samples were made in duplicate and stored at + 4 C° until analysed.

2.2. Methods

2.2.1. Peanut Butter Making

Peanut butter was made in the laboratories at Osmaniye Korkut Ata University. The amounts of raw materials used in the production of peanut butter are given in Table 1. For each sample, 400 g roasted and peeled peanuts, 3g salt, 20g peanut oil, and different proportions of carob molasses [(2.5%), (5%), (10%), (20%)] and carob powder [(2.5%), (5%), (10%), (20%)] were added and grinded in the blender until it reached a spreadable consistency. Also, a control sample was produced without adding any carob molasses or carob powder. A total of 9 different peanut butter samples were produced and coded as 1 (control), 2 (2.5% CM), 3 (5% CM), 4 (10% CM), 5 (20% CM), 6 (2.5% CP), 7 (5% CP), 8 (10% CP), and 9 (20% CP).

2.2.2. Rheological Analyses

The HAAKE Rheometer (Thermo Scientific HAAKE GmbH, Karlsruhe, Germany) was used for rheological measurements. The device is a controlled stress rheometer equipped with a TCP/P Peltier temperature control unit. A cone-and-plate sensor (diameter = 3.5 cm and angle = 2°) attached to the rheometer was used for rheological measurements for the peanut butter samples at shear rates of 0-50 1/s. In addition, rheological analyzes were carried out in triplicate.

2.2.3. Statistical Analysis

Rheological findings were calculated by nonlinear regression method and using Sigma Plot software (Scientific Graph System, version 11.0, SPSS Inc., Chicago, IL).

Table 1. *The Amounts of Raw Materials in Peanut Butter Composition*

Raw Materials	**Peanut Butter Samples**								
	1	2	3	4	5	6	7	8	9
Peanut Butter (g)	400	400	400	400	400	400	400	400	400
Peanut Butter Oil (g)	20	20	20	20	20	20	20	20	20
Salt (g)	3	3	3	3	3	3	3	3	3
Carob Molasses (g)	–	10	20	40	80	–	–	–	–
Carob Powder (g)	–	–	–	–	–	10	20	40	80

3. RESULTS AND DISCUSSION

Rheological properties of peanut butter should be known in terms of determining its consistency, texture and quality. The shear rate - shear stress values of the peanut butter samples obtained by adding carob molasses and carob powder are presented in a graph and the results are given in Figure 1, Figure 2, and Figure 3. As can be seen in all three figures, the samples exhibited non-Newtonian pseudoplastic flow behaviour. The current study is similar to some relevant previous studies on peanut butter. Sun and Gunasekaran (2009) reported that the peanut butter samples exhibited non-Newtonian pseudoplastic flow behaviour in their study. In another study on the rheological properties of peanut butter by Li et al. (2014), the authors indicated that peanut butter showed non-Newtonian pseudoplastic flow.

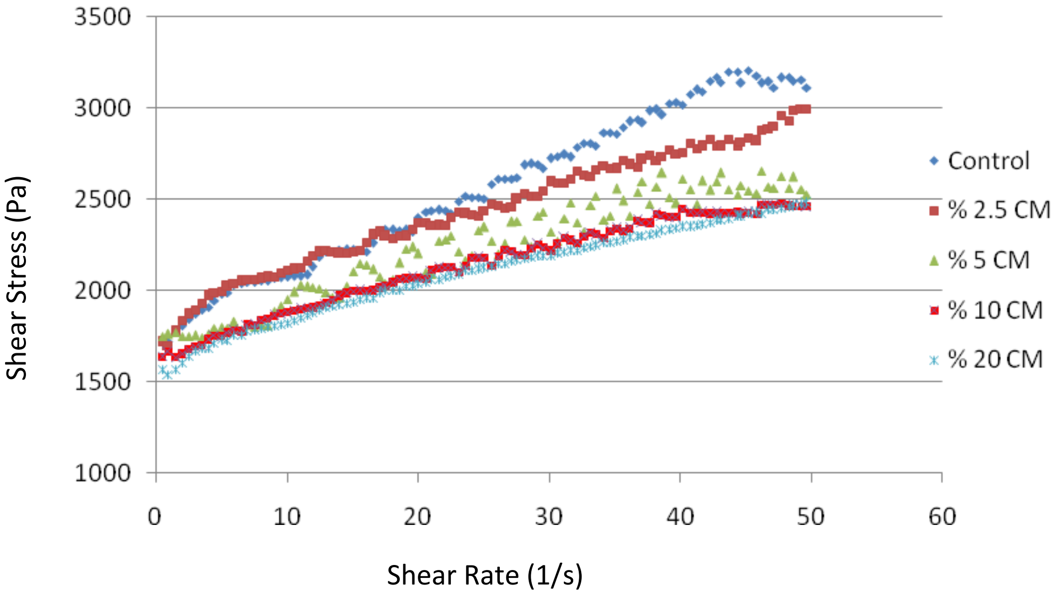

Figure 1. Shear stress - shear rate changes of carob molasses-added peanut butter samples, Control: 0%, CM: Carob molasses.

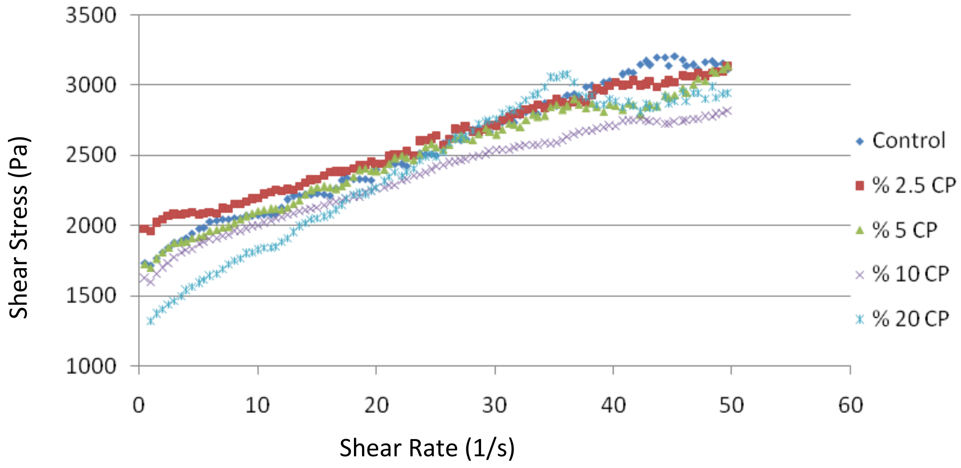

Figure 2. Shear stress - shear rate changes of carob powder-added peanut butter samples, Control: 0%, CP: Carob powder.

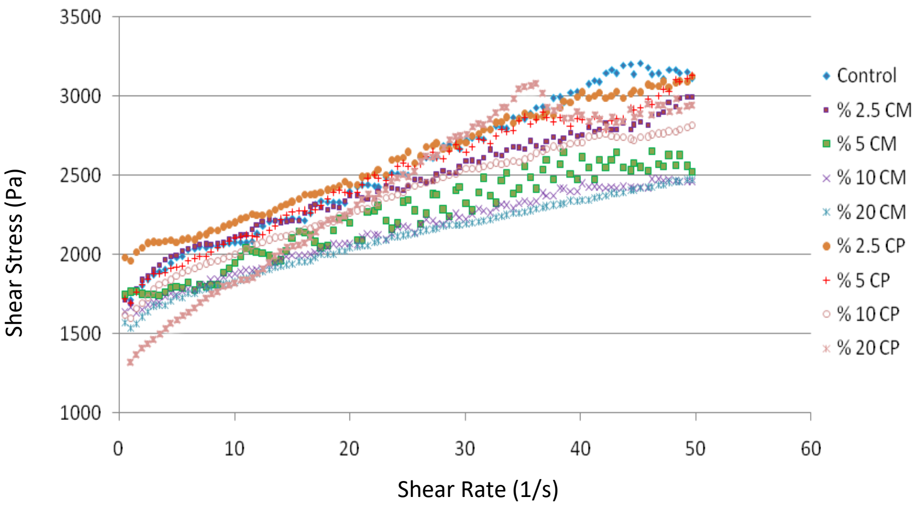

Figure 3. Shear stress - shear rate changes of carob molasses and carob powder-added peanut butter samples, Control: 0%, CM: Carob molasses, CP: Carob powder

On the other hand, the shear rate and viscosity values of the peanut butter sample to which carob molasses and carob powder were added are presented in a graph, and the results are given in Figures 4, 5, and 6. The viscosity values were found to have decreased depending on the shear rate in all samples examined, which all showed non-Newtonian pseudoplastic flow behaviour. As can be seen from the figures, the viscosity generally decreased as the amount of carob molasses and carob powder, which were added to peanut butter samples, increased, which may be attributed to the particle structure of carob molasses and carob powder. Possibly, the reduction in oil content may also be the reason for the lower viscosity. Norazatul et al. (2016) reported in a study on peanut butter that viscosity increased with the increase in the amount of oil. Similarly, Emadzadeh et al. (2012)

stated that the consistency coefficient and viscosity values of the peanut butter samples increased in parallel with the increase in the amount of oil. Also, the particle sizes in carob molasses and carob powder may have reduced viscosity as they are smaller than those of peanut butter. Çiftçi et al. (2008) examined the effect of particle structure on the rheological properties of sesame tahini. The authors reported that the higher was the particle size, the higher was the viscosity, as opposed to decreasing colloidal stability. For such reasons, it can be assumed that viscosity is likely to decrease due to the increased amount of carob molasses and carob powder. Also, Li et al. (2014) examined the effect of sorbitol additive on the rheological properties of peanut butter and found that the viscosity decreased as the sorbitol concentration increased.

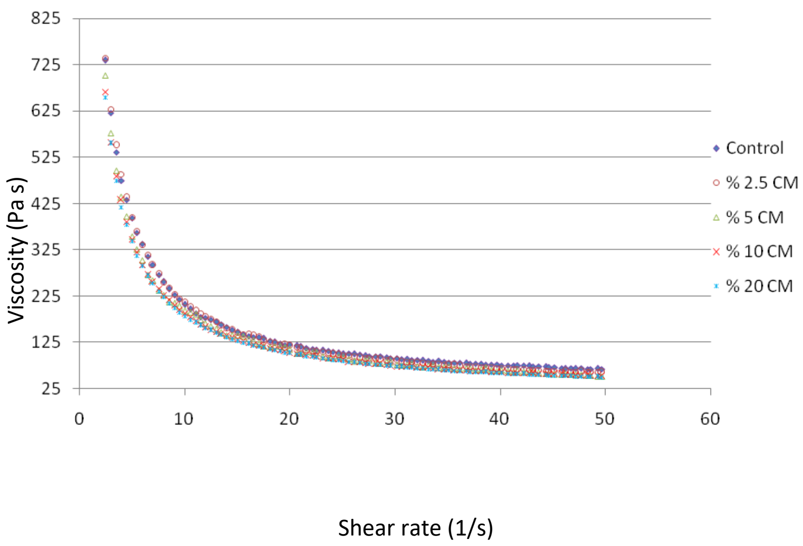

Figure 4. Viscosity-shear rate changes of carob molasses-added peanut butter samples, Control: 0%, CM: Carob molasses

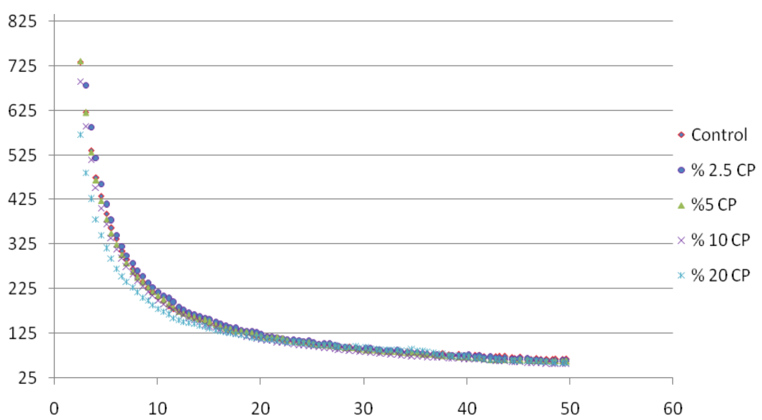

Figure 5. Viscosity-shear rate changes of carob powder-added peanut butter samples, Control: 0%, CP: Carob powder

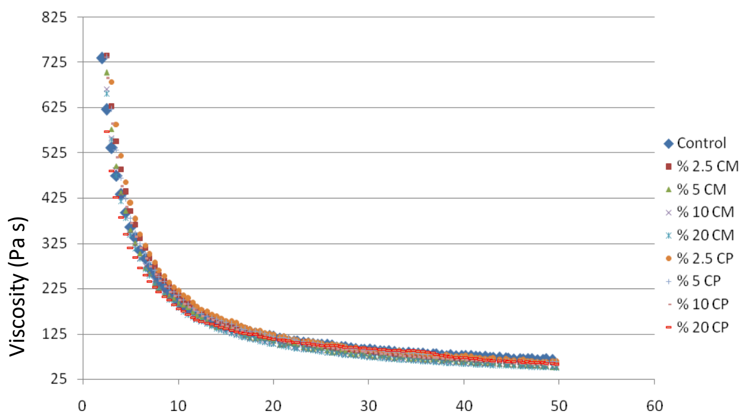

Figure 6. Viscosity-shear rate changes of carob molasses- and carob powder-added peanut butter samples, Control: 0%, CM: Carob molasses, CP: Carob powder

As can be seen in Figure 3, when the peanut butter samples involving similar proportions of carob powder and carob molasses were compared, the samples with carob powder appeared to have a higher viscosity compared to the ones with carob molasses, which is attributed to the composition of carob powder and carob molasses. Özcan et al. (2007) examined the chemical composition of carob fruit, carob powder, and carob molasses. The authors reported that carob powder has 3.81 times more protein and 3.49 times more insoluble pulp when compared to carob molasses. Bilgiçli (2004) reported that proteins increase the viscosity in food items. Similarly, Seena and Sridhar (2005) emphasized that proteins increase viscosity. In addition, Grigelmo-Miguel et al. (1999) stated that the pulp plays the role of adjusting and increasing the viscosity of foods.

The viscosity of peanut butter can be described with the Herschel-Bulkley model since it shows non-Newtonian properties

$\tau = \tau_0 + k\,\gamma^n$

τ= shear stress (Pa), τ_0= yield stress according to Herschel-Bulkley (Pa), k= flow coefficient (Pa s^n), γ= shear rate (1/s), n= flow behaviour index

Peanut butters made by adding carob molasses and carob powder in different proportions was evaluated according to the Herschel-Bulkley model, and the results are given in Table 2. The R2 values of the samples varied between 0.9753-0.9988, leading to the assumption that the rheological properties of peanut butter fit the Herschel-Bulkley model. Sun et al. (2009) examined the rheological properties of peanut butter and identified their flow properties based on the Herschel Bulkley model. Likewise, Li et al. (2014) defined the rheological properties of peanut butter with Herschel-Bulkley. Our study has similarities with the relevant studies in the literature.

The yield stress value must be kept low in order to ensure that peanut butter is fluid since this value affects its spreadability.

Table 2. *Herschel-Bulkley model values of carob molasses- and carob powder-added peanut butter samples*

Peanut Butters	τ_0 (Pa)	k (Pa·s^n)	n	R^2
Control	1734	43.60	0.91	0.9897
%2.5 CM	1727	70.39	0.73	0,9958
%5 CM	1609	68.02	0.70	0,9753
%10 CM	1562	64.17	0.69	0,9933
%20 CM	1494	75.52	0,66	0,9988
%2.5 CP	1933	35.24	0,91	0,9918
%5 CP	1611	105.2	0,67	0,9941
%10 CP	1499	130.1	0,60	0,9970
%20 CP	920	304.8	0,51	0,9759

Control: 0%, CM: Carob molasses, CP: Carob powder

If the yield stress is excessive, the texture of the peanut butter hardens and its spreadability decreases, whereas if the yield stress is small, the viscosity and spreadability of the peanut butter improve. As can be seen from Table 2, the yield stress decreases as more molasses is added to the peanut butter and the added molasses concentration is increased. It also decreases when carob powder is added to the peanut butter, and especially when the amount of carob powder is increased. It appears that the addition of carob molasses and carob powder to the peanut butter samples decreases the yield stress values as the concentration increases. This is related to the fact that adding carob molasses and carob powder to peanut butter reduces the viscosity of the samples.

Adding carob molasses and carob powder to peanut butter was found to increase the flow coefficient (k) while decreasing the flow index (n) value. In this way, the pseudoplastic properties of the samples decreased, the particle arrangement of the peanut butter changed and the viscosity of the peanut butter decreased as its network structure was disrupted. In a study conducted by Li et al. (2014), the authors determined that the yield stress and flow index values of the samples obtained by adding sorbitol to peanut butter decreased with the addition of sorbitol, and that such values varied between (-1.21) - 28.38 and 0.55-1.17, respectively. Davis et al. (2007) stated in their study on peanut butter that the flow coefficient, yield stress and flow index varied between 0.1-0.49, 0.13-2.29, and 0.66-0.90, respectively.

4. CONCLUSION

The effects of using different proportions of carob molasses (2.5%, 5%, 10% and 20%) and carob powder (2.5%, 5%, 10% and 20%) on the rheological of peanut butter were analysed in this study. The peanut butter samples showed non-Newtonian pseudoplastic flow behaviour and rheological properties of the peanut butter samples were defined with the Herschel-Bulkley model. The results revealed that viscosity, yield stress (□0), and flow index (n) values of the peanut butter samples decreased upon adding carob molasses or carob powder, due to increased concentration.

CONFLICT OF INTEREST STATEMENT

No potential conflict of interest was reported by the authors.

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