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THE EFFECT OF APRICOT FIBRE ADDITION ON THE RHEOLOGICAL PROPERTIES AND MINERAL CONTENT OF PEANUT BUTTER

KAYISI LİFİ İLAVESİNİN YER FISTIĞI EZMESİNİN REOLOJİK ÖZELLİKLERİNE VE MİNERAL MADDE İÇERİĞİNE ETKİSİ

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ABSTRACT

In this study, the effect of apricot fibre addition at different ratios (0%, 1%, 2%, 4%, 8%, and 16%) on the rheological properties and mineral matter composition of peanut butter was investigated. In terms of rheological properties, peanut butter showed non-Newtonian flow behaviour, and the results were expressed by Ostwald de Waele model. As the amount of apricot fibre increased, the viscosity values in peanut butter generally decreased. In terms of mineral matter, as the amount of apricot fibre increased, the amounts of Fe and Ca in peanut butter increased, while the amounts of K and Mg decreased ($p<0.05$). It can be said that the addition of apricot fiber improves the structure of peanut butter.

Keywords: Peanut butter, apricot fibre, rheology, mineral matter

ÖZET

Bu çalışmada, farklı oranlarda kayısı lifi (%0, %1, %2, %4, %8 ve %16) ilavesinin yer fıstığı ezmelerinin reolojik özelliklerine, mineral madde bileşimi üzerindeki etkisi araştırılmıştır. Reolojik özellikler bakımından, yer fıstığı ezmeleri Newtonyen olmayan (Non-Newtonian) akış davranışı göstermiş ve sonuçlar Ostwald de Waele modeli ile ifade edilmiştir. Kayısı lifi miktarı arttıkça yer fıstığı ezmelerindeki viskozite değerleri genellikle azalma göstermiştir. Mineral madde açısından, kayısı lifi miktarı arttıkça, yer fıstığı ezmelerindeki Fe, Ca miktarları artış göstermiş iken, K ve Mg miktarlarında azalma olduğu saptanmıştır($p<0.05$). Yer fıstığı ezmesine kayısı lifi ilavesinin yapısını iyileştirdiği söylenebilir.

Anahtar Kelimeler: Yer fıstığı ezmesi, kayısı lifi, reoloji, mineral madde

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INTRODUCTION

Peanuts (Arachis hypogaea) are a valuable source of nutrition, rich in monounsaturated fats, dietary fiber, proteins, minerals, and antioxidants (Esche et al., 2013). Incorporating peanuts into a balanced diet can help lower the chances of developing coronary heart disease, cancer, and Alzheimer's disease (Shin et al., 2009).

Peanut butter is typically made by roasting and grinding raw peanuts, resulting in its unique taste and flavor. It offers numerous health benefits (Hashemian et al., 2017; Gong et al., 2018). The composition of peanut butter consists of solid particles dispersed in a continuous oil phase, forming a thick suspension (Norazatul et al., 2016). The quality of the peanuts used in production plays a crucial role in determining the overall quality of the final peanut butter product.

Peanut butter is a healthy food, thanks to its nutrient-dense composition. However, to boost its popularity, improvements in its composition, functional properties, and overall quality are necessary.

Apricot (Prunus armeniaca L.) is a fruit belonging to the Prunus genus within the Rosaceae family of the Rosales order. It is enjoyed either fresh or processed into various products, such as dried apricots, fruit juice, nectar, jelly, jam, and extruded snacks (Özbek, 1978).

Apricot is rich in sugars, bioactive phytochemicals, fiber, minerals, and vitamins, including A, C, thiamine, riboflavin, niacin, and pantothenic acid. Among its phytochemical content, phenolic compounds, carotenoids, and antioxidants are particularly significant due to their biological value (Hacıseferoğulları et al., 2007; Ali et al., 2011).

Dietary fibers should be consumed regularly for optimal health. Initially, their significance for health was not widely recognized, but recent understanding has established them as a key component of a healthy diet. Studies conducted in recent years have highlighted the vital role of fibers in human health, leading to an increased demand for their inclusion in the production of functional foods. In response, several high-fiber formulated foods have been developed to harness the functional benefits of dietary fiber (Herbafood, 2002). For dietary fiber to be accepted in a food product, it must effectively function as a beneficial food ingredient (Jaime et al., 2002).

Fruit fibers are consumed less frequently than cereal fibers. However, fruit fiber offers superior quality, characterized by higher soluble fiber content, better water and fat retention capacities, and fewer calories compared to cereal fibers (Larrauri, 1999).

Most studies involving apricots have focused on their use in products such as bread, cakes, crackers, cookies, and yogurt (Karaca et al., 2019; Ağırbaş et al., 2021; Nisar et al., 2021; Yao et al., 2021). No research has been found in the literature regarding the production of peanut butter with added apricot fiber.

Determining the rheological properties of peanut butter is essential for understanding its structure, consistency, and overall quality. Rheology is the scientific field that focuses on the deformation and flow of materials. The mechanical properties that lead to deformation and flow under applied forces are referred to as rheological properties. In the food industry, the rheological characteristics of food products are crucial for designing equipment such as pipelines, pumps, extruders, mixers, coating machines, heat exchangers, and homogenizers, as well as for optimizing processes associated with these machines (Davulcu, 2012; Bozdogan, 2015; Bozdogan, 2017; Çavdır et al., 2020).

This study investigated the effect of incorporating apricot fiber at different levels on the mineral content and rheological properties of peanut butter.

MATERIAL AND METHOD

Material

Raw material

Apricots purchased from the fruit and vegetable market in Osmaniye, Türkiye, were used in fibre production. Apricots were grown in Mersin Mut region. The peanuts used in the production of peanut butter were obtained from Bağdatlılar Trading Dried Fruits and Nuts Industry Co. Ltd. in Osmaniye, Türkiye.

Methods

In the production of peanut butter, the peanut crushing machine of Bağdatlılar Trading Dried Fruits and Nuts Industry Co. Ltd. (XUANHUA, China) was used. In apricot fibre production, an oven (ON-O2G Oven) was used for apricot drying. The size reduction of dried apricots was carried out with a blender (Arçelik, Turkey). Rheological measurements were carried out using a Thermo Scientific Viscotester (Haake GmbH, Karlsruhe, Germany) rheometer. pH values were measured with Orion Star™ A 211 pH Benchtop Meter digital pH meter (Inolab, Weilhem, Germany). Konica Minolta colorimeter (Chroma Meter CR-400, Japan) was used for colour measurement.

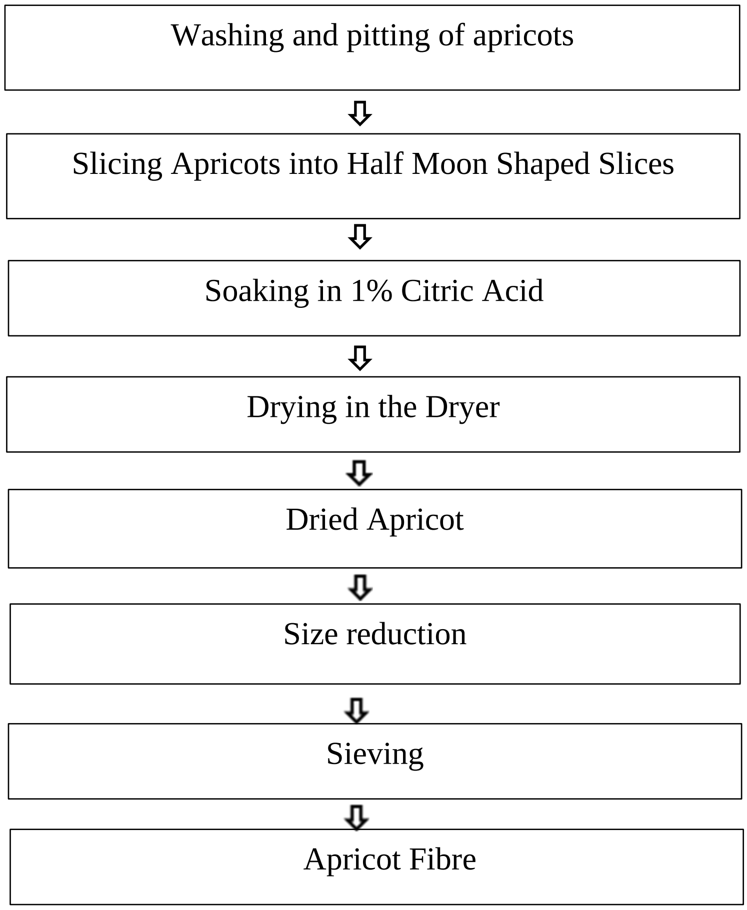

Figure 1. Apricot Fibre Production Flow Chart

Preparation of Apricot Fibre

Apricot fibre production was carried out in the laboratory of Osmaniye Korkut Ata University, Department of Food Engineering. Fresh 10 kg apricots from Mut, Mersin, Türkiye region obtained from Osmaniye, Türkiye Fruit and Vegetable market were washed with potable water and pitted. The apricots were sliced longitudinally into half moon shapes. Apricot slices were soaked in water containing citric acid (1%, w/v) to prevent browning. Apricot slices removed from the water containing citric acid were placed on aluminum trays and left at room temperature to remove moisture. For drying, they were kept in an oven at 66 °C for 90 hours. The dried apricot slices were blended and pulverized. The coarse particles were sieved to remove and retained, and apricot fibres were obtained.

Addition of Apricot Fibre to Peanut Butter

The inner peanuts were roasted in an oven at 145ºC with 1% moisture content. Afterwards, membrane peeling and selection (foreign matter, unsuitable peanuts) were performed. As can be seen in Table 1, apricot fibre was added to the selected peanuts at the rates of 1%, 2%, 4%, 8%, and 16%, respectively, and these mixtures were drawn in the peanut butter production machine. In addition, peanut butter without added apricot fibre was also produced as a control product. The peanut butters were filled into 3 kg glass jars and stored in the refrigerator until analysed.

Table 1. Amounts of Apricot Fibre Added to Peanut Butter

Raw materials	Control	1%	2%	4%	8%	16%
Peanut (g)	3000	2970	2940	2880	2760	2520
Apricot Fibre (g)	-	30	60	120	240	480

Analyses of Apricot Fibre Peanut Butter

The analyses of the samples were carried out at Osmaniye Korkut Ata University Food Engineering Department and the Central Laboratory of the University.

Rheological Analyses

Rheological analysis was performed using a Thermo Scientific Viscotester rheometer (Haake GmbH, Karlsruhe, Germany). This controlled stress rheometer was equipped with a TCP/P Peltier temperature control unit and a cone-and-plate sensor (diameter = 3.5 cm, angle = 2º). Rheological measurements of peanut butter with added apricot fiber were conducted at shear rates ranging from 0 to 100 1/s. Shear stress values were plotted against shear rate, and viscosity values were also measured in relation to shear rate. Additionally, the effect of temperature on the rheological properties of peanut butter was analyzed by examining shear stress as a function of shear rate.

Mineral Matter Analysis

Mineral matter (Cu, Mn, Fe, Zn, K, Na, Ca, Mg, P) was analyzed by an atomic absorption device (Agilent 250 FS, USA) according to AOAC (Anon, 1990).

Statistical Analysis

Analysis of variance (ANOVA) was conducted on the mineral matter results, and differences between the groups were assessed using the Duncan multiple comparison test. The statistical analysis was performed using the SPSS 18.0 software (SPSS Inc., Chicago, IL, USA). Additionally, rheological data were analyzed using the non-linear regression method.

RESEARCH FINDINGS AND DISCUSSION

Mineral Composition of Peanut Butter

Peanuts serve as a valuable dietary source of macro minerals, which are essential nutrients required by the body in amounts exceeding 100 mg per day (Derise et al., 1974; Settaluri et al., 2012).
The results of the mineral composition of apricot fibre added peanut butters are given in Table 2.

AF: Apricot Fibre. The difference between the values shown with different letters from left to right in the same row is statistically significant ($p<0.05$).

The mineral composition of peanut butters varied between 0.72-0.93 mg/kg copper, 11.36-14 mg/kg manganese, 25.82-49.62 mg/kg iron, 34.38-39.88 mg/kg zinc, 4652.5-13517.5 mg/kg potassium, 205-342.5 mg/kg sodium, 593.5- 852.5 mg/kg calcium, 1253.5-1798.5 mg/kg magnesium and 2913.5-3325 mg/kg phosphorus.

Cu, Mn, Zn, Na, and P minerals were found to be statistically insignificant ($p>0.05$). In terms of Fe, K, and Ca minerals, the differences between the peanut butters were found to be significant ($p<0.05$). It was determined that Fe, K, and Ca minerals increased as the amount of apricot fibre increased. In terms of Mg, it was determined that the difference between peanut butters was statistically significant ($p<0.05$). It was determined that Mg minerals decreased as the amount of apricot fibre increased.
Iron plays a crucial role in the production of heme in blood and facilitates oxygen transport throughout the body. Potassium, abundant in peanuts, helps maintain electrolyte balance while supporting muscle and neurological functions. Calcium is essential for the development of bones and teeth, as well as for protein synthesis, which is vital for tissue growth and repair (Settaluri et al., 2012)

Table 2. Mineral Composition of Peanut Butters

	Peanut Butter					
Mineral matter (mg/kg)	**Control**	**1% AF**	**2% AF**	**4% AF**	**8% AF**	**16% AF**
Cu	0.72±0.1	0.92±0.2	0.79±0.2	0.84±0.1	0.85±0.3	0.93±0.6
Mn	12.75±0.7	14.00±2.8	12.88±0.2	12.20±1.2	12.75±1	11.36±0.3
Fe	26.12^{c}±5.8	26.75^{c}±3.8	25.82^{c}±1.5	33.00^{b}±2.1	33.00^{b}±0.0	49.62^{a}±0.2
Zn	37.38±1.9	39.88±4.7	36.75±0.4	34.63±3	36.00±1	34.38±0.5
K	4652.50^{c}±166	9400.00^{b}±1944	7510.00^{b}±459	12955.00^{a}±226	13195.00^{a}±113	13517.50^{a}±116
Na	220.00±49	218.50±11	233.50±3.5	205.00±28	245.00±21	342.50±67
Ca	593.50^{c}±32	598.50^{c}±39	653.50^{b}±11	623.50^{b}±4	780.00^{ab}±56	852.50^{a}±53
Mg	1698.50^{a}±82	1798.50^{a}±215	1712.50^{a}±4	1253.50^{b}±46	1330.00^{b}±64	1268.50^{b}±39
P	3138.50±124	3325.00±36	2925.00±35	2913.50±512	3250.00±141	3288.50±18

The limits determined by USDA (2024) are average values per 100 g and are shown as copper 0.47 mg/kg, manganese 14.66 mg/kg, iron 18.70 mg/kg, zinc 29.10 mg/kg, potassium 6490 mg/kg, sodium 170 mg/kg, calcium 430 mg/kg, magnesium 1540 mg/kg and phosphorus 3850 mg/kg. Copper, manganese, iron, zinc, potassium, sodium, and calcium values of apricot fibre added peanut butter were found to be higher than the specified limits. The phosphorus value remained below the limit.

Shibli, et al. (2019) determined that iron 16.5-19.6 mg/kg, zinc 15.1-19.7 mg/kg, potassium 6611.4-8208.6 mg/kg, sodium 6031.6-7908.7 mg/kg, calcium 580.6-644.5 mg/kg, magnesium -2033 mg/kg and phosphorus 2451.1-2644.6 mg/kg in peanut butter obtained from different peanuts. When compared with the mineral compositions of apricot fibre added peanut butters, it was observed that the values in the literature were higher than the values of this study. This may be due to the variety of peanuts and the soil and climate structure of the region where peanuts are grown.

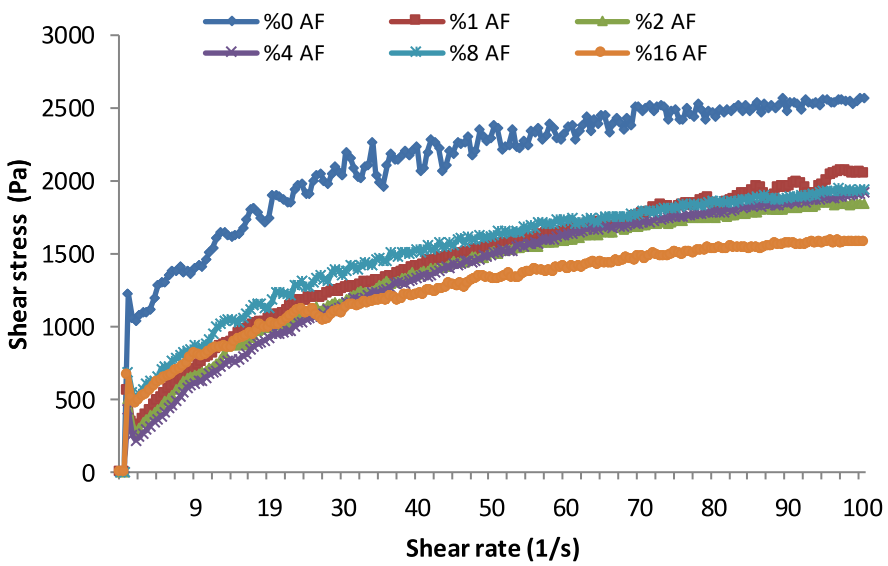

Figure 2. Shear Stress-Shear Rate Variation of Peanut Butter (20°C)

Rheological Properties of Peanut Butter

The rheological properties of peanut butter obtained by adding apricot fibre at different ratios (1%, 2%, 4%, 8%, and 16%) were investigated at shear rates of 0-100 1/s. The shear stress values of peanut butter samples versus shear rate were plotted, and the graphs are given in Figure 2, Figure 4, and Figure 6.

Shear stress indicates that a minimum stress is required to achieve flow. The presence of shear stress in apricot fibre added peanut butter products is due to the large number of peanut and apricot fibre particles in the oil dispersion in the suspension. Therefore, the viscosity decreased as the amount of apricot fibre increased.

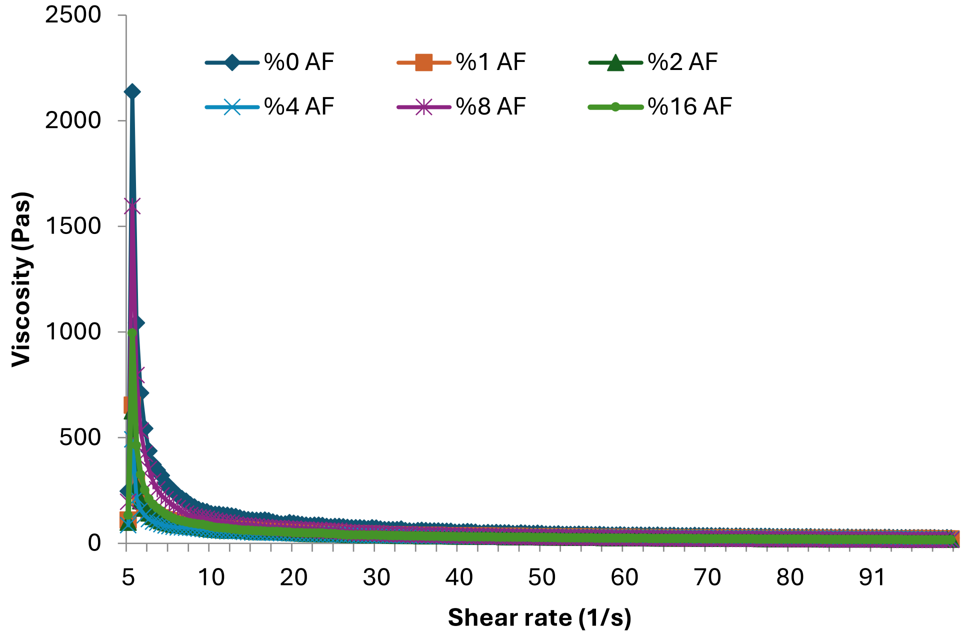

Figure 3. Viscosity-Shear Rate Variation of Peanut Butters (20°C)

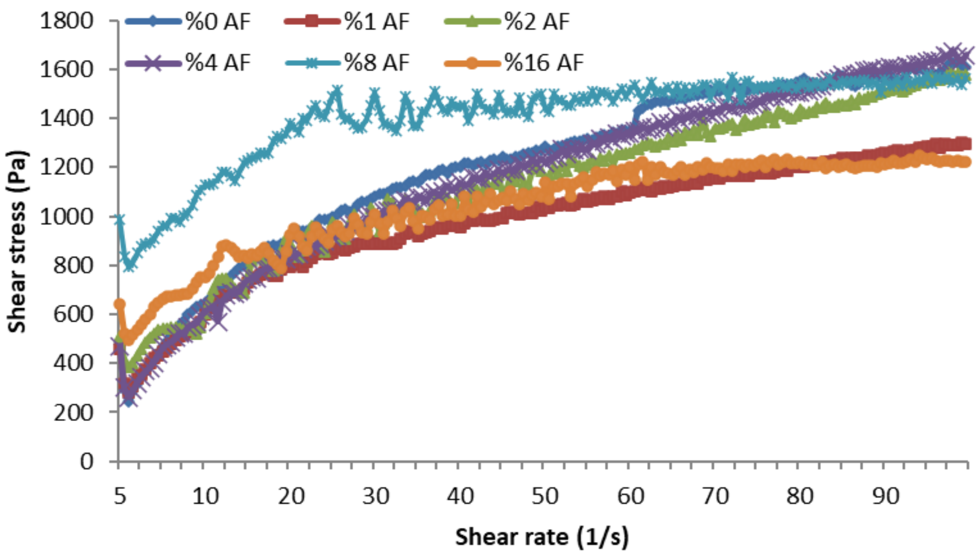

Figure 4. Shear Stress-Shear Rate Variation of Peanut Butter (30°C)

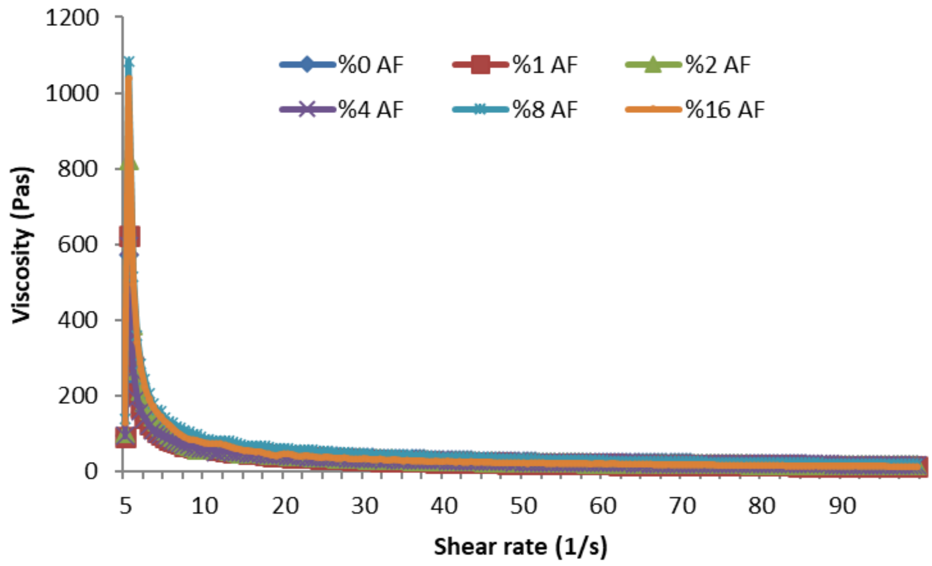

Figure 5. Viscosity-Shear Rate Variation of Peanut Butters (30°C)

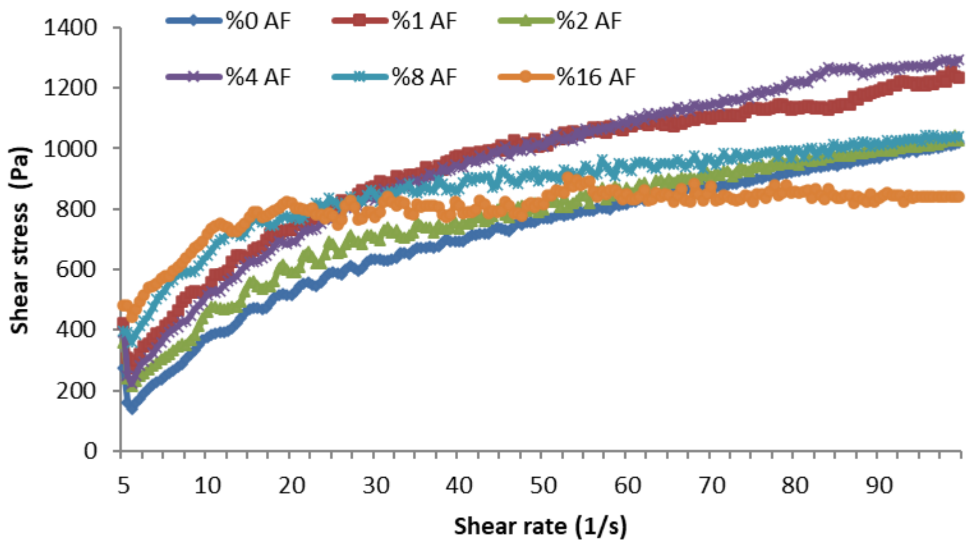

Figure 6. Shear Stress-Shear Rate Variation of Peanut Butter (40°C)

The shear rate-shear stress values of peanut butter with added apricot fiber were determined to demonstrate non-Newtonian flow behavior, as illustrated in Figure 2, Figure 4, and Figure 6.

The shear rate-viscosity values of peanut butter were plotted on graphs, as shown in Figure 3, Figure 5, and Figure 7. It was observed that as the shear rate increased, the viscosity values decreased. These graphs confirmed that the apricot fiber-added peanut butter exhibited non-Newtonian flow characteristics.

Sun and Gunasekaran (2009), Li et al. (2014), and Yu et al. (2021) observed that peanut butter exhibits non-Newtonian pseudoplastic flow behavior in their rheological studies, with calculations made using the Herschel-Bulkley model. Similarly, a study by Tanrıkulu et al. (2022) also concluded that peanut butter demonstrated non-Newtonian pseudoplastic flow behavior.

Ostwald de Waele model $\tau = k\gamma^n$ successfully explains the rheological data of apricot fibre added peanut butter samples. The Ostwald de Waele model values of the peanut butter samples are given in Table 3.

Shear stress (τ) : Pa
Shear rate (γ) : 1/s
Consistency coefficient (k): Pa sn

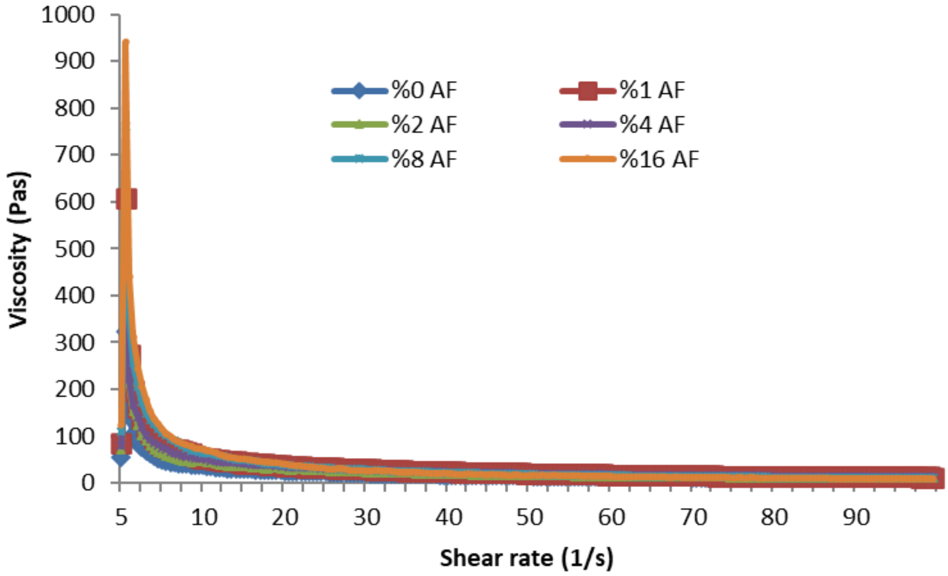

Figure 7. Viscosity-Shear Rate Variation of Peanut Butters (40°C)

As the amount of apricot fiber added to peanut butter increased, the consistency coefficient (k) values decreased up to the sample with 4% AF addition. Fluctuations were observed starting from the sample with 8% AF addition. The highest consistency coefficient value was determined in the sample without apricot fiber addition (control). Flow index (n) values varied between 0.1079-0.4628.

Davis et al. (2007) found flow index values between 0.66-0.99 in a rheological study on peanut butter. In the study conducted by Li et al. (2014), the flow index values of sorbitol added peanut butter varied between 0.55-1.17. Compared to these studies, the flow index values of apricot fibre added peanut butter were found to be high.

As shown in the shear rate-viscosity graphs in Figure 3, Figure 5, and Figure 7, which illustrate the effect of temperature on the rheological properties of peanut butter, it was observed that viscosity decreased with an increase in temperature. Furthermore, it was determined that both the viscosity coefficient and flow index values decreased as the temperature increased (Table 3).

This suggests that as the temperature increases, the optimized emulsifying agent mixture loses its functionality, leading to a significant degradation of the structure. A similar study on the effect of temperature and fat content on the apparent viscosity of coconut milk samples found that an increase in fat content reduced the impact of temperature on changes in apparent viscosity (Simuang et al., 2004).

Taghizadeh et al. (2009) explained the flow behaviour with Herschel-Bulkley model in a time independent rheological study on peanut butter. At 25°C, the flow behaviour indices ranged from 0.517 to 0.792, and at 45°C, the flow behaviour indices ranged from 0.401 to 0.806, respectively, indicating that all samples exhibited non-Newtonian pseudoplastic behaviour. When compared with the literature and the present study, the flow index of apricot fibre added peanut butters remained low.

CONCLUSIONS

The impact of varying ratios of apricot fiber (0%, 1%, 2%, 4%, 8%, and 16%) on the mineral and rheological properties of peanut butter was investigated. As the amount of apricot fibre increased, the amounts of Fe and Ca in peanut butter increased. However, it was found that the amounts of K and Mg decreased. In terms of rheological properties, it was determined that the viscosity of the product decreased as the apricot fibre content increased. Peanut butter showed non-Newtonian pseudoplastic flow behaviour, and the results were expressed by Ostwald de Waele model. As a result, the addition of apricot fiber improved the texture and consistency of peanut butter.

Table 3. Values of the Ostwald de Waele Model or Peanut Butter

Peanut butter	k (Pa·s^n)	n	R^2
Control 20°C	940.9	0.2225	0.9855
Control 30°C	284.6	0.3843	0.995
Control 40°C	143.9	0.4248	0.9983
1% AF 20°C	303	0.4147	0.9977
1% AF 30°C	292.2	0.3235	0.9972
1% AF 40°C	277.3	0.3266	0.9932
2% AF 20°C	293.7	0.4088	0.995
2% AF 30°C	276.2	0.3744	0.9935
2% AF 40°C	203.6	0.3534	0.9948
4% AF 20°C	236.8	0.4628	0.995
4% AF 30°C	228.3	0.4315	0.9991
4% AF 40°C	215.3	0.3938	0.9976
8% AF 20°C	461.7	0.3174	0.9946
8% AF 30°C	432.3	0.2429	0.9564
8% AF 40°C	413.1	0.2014	0.9889
16% AF 20°C	411	0.2974	0.9966
16% AF 30°C	467.2	0.2171	0.9858
16% AF 40°C	538.8	0.1079	0.9087

AF: Apricot Fibre

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