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Evaluation of the Influence of Honey Incorporation on the Rheological Properties of Peanut Butter

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Abstract

The present research investigated how the addition of pine honey (PH), chestnut honey (CH), and highland honey (HH) at different inclusion levels (2.5%, 5%, and 10%) influences the rheological and sensory behavior of peanut butter. Rheological analysis revealed that all samples displayed non-Newtonian flow behavior, and the experimental data were well described by the Herschel–Bulkley model. The incorporation of honey led to an increase in the viscosity of peanut butter, with the highest values observed in samples containing PH, followed by those with HH and CH, respectively. In the sensory evaluation, panelists assessed attributes including oiliness, fluidity, texture, stickiness, taste, color, and overall impression. Among the samples, the peanut butter containing 5% PH received the highest preference score from the panelists. Therefore, the formulation incorporating 5% PH was determined to be optimal for peanut butter production

Keywords: Ozone, protein, optical activity, DSC, HPLC.

1.INTRODUCTION

Although its flowers bloom above ground, the peanut is one of the rare legume species whose fruit develops underground. Originating in South America, this plant was first cultivated by pre-Columbian civilizations in Peru around 3000 BC. Today, peanut cultivation has expanded considerably due to the development of improved genetic varieties and advancements in modern agricultural practices, including irrigation, fertilization, and pest and disease management. These advances have allowed for more efficient use of favorable environmental conditions. Furthermore, the development of international trade, standardization, and the implementation of cold chain technologies have largely eliminated transportation problems from harvest to consumption (Sanders, 2003).

The physical properties of soil strongly influence the growth and productivity of peanut plants, as soil texture regulates the transport of water, nutrients, gases, and heat within the soil matrix. Research conducted in Shandong Province has provided important data for regional production strategies and soil improvement practices by examining peanut growth performance in different soil types. The most suitable period for peanut planting in the Mediterranean climate zone is reported to be from late April to mid-May. Osmaniye Province, in particular, offers a favorable ecological environment for peanut cultivation thanks to its warm and humid climate and well-drained soil structure (Zhao et al., 2015). Approximately 90% of Turkey's peanut trade volume is reported to occur in this region. These favorable conditions and increased production have contributed to the wider distribution of processed peanuts, especially peanut butters, in global markets (Aşık et al., 2015).

Peanut butter is a nutritious food product obtained by grinding roasted peanuts and widely consumed worldwide. Thanks to its high protein and fat content, it is an important source of energy and is often used in breakfasts, sandwiches, and various desserts (Tarıkulu et al., 2022a). It can also be used as an additive in various recipes, enriching both flavor and nutritional value. The healthy fatty acids found in peanuts and the antioxidant compounds in their shells make them a functional food. Regular consumption can contribute to supporting a balanced diet in all age groups, ensuring weight control, and preventing some chronic diseases (Tarıkulu et al., 2022b; Woodroof, 1983).

Honey is a highly viscous natural foodstuff formed by bees collecting plant nectar or pine secretions and transforming them through biochemical processes. It contains high amounts of sugars, organic acids, certain amino acids, and macro- and micronutrient elements, giving it a high nutritional value (Juszczak and Fortuna, 2006). Determining the rheological properties of honey is crucial for understanding product behavior during production, determining appropriate process conditions, predicting shelf life, monitoring changes during storage, and ensuring quality control (Steffe, 1996). Viscosity is the most critical rheological parameter. The viscosity of honey is affected by factors such as its chemical composition, botanical and geographical origin, humidity, temperature, and structural properties.

This study investigated the impact of adding varying amounts (2.5%, 5%, and 10%) of pine honey (PH), chestnut honey (CH), and highland honey (HH) to peanut butter on its rheological and sensory properties, with the aim of enhancing the product's functional qualities.

2. MATERIAL AND METHODS

2.1. Raw materials

Pine honey (PH), chestnut honey (CH), and highland honey (HH) samples used in this study were supplied by Altıparmak Food Industry and Trade Inc. in Istanbul. The peanuts used in the production of peanut butter were supplied by Bağdatlılar Industry Co. Ltd. in Osmaniye, Türkiye.

2.2 Method

The peanuts were roasted in an oven at 145°C to reduce the moisture content to 1%. Following roasting, the skin peeling and physical sorting (removal of foreign matter and defective kernels) were applied. The roasted peanuts were ground using a grinder suitable for peanut butter production (XUANHUA, China), and homogeneous peanut butter was obtained. The resulting butters were divided into 10 different groups. Pine honey (PH), chestnut honey (CH), and highland honey (HH) were used as sweeteners in the production. Each type of honey was added separately at 2.5%, 5%, and 10% to samples except the control group. Homogenization of the mixtures was achieved using an ultrasonic bath for 15 minute. The prepared peanut butter samples were packaged in 1 kg plastic jars and stored under refrigeration until analysis. All experiments were performed in duplicate.

2.3. Analyses of Peanut Butter

Analyses of the peanuts butter were carried out in two parallels.

2.3.1. Rheological Analyses

The rheological characteristics of the peanut butter were analyzed using a Thermo Scientific Rheometer (Haake GmbH, Germany). This device is a stress-controlled rheometer equipped with a TCP/P-type Peltier temperature control unit. A cone-plate sensor (diameter 3.5 cm, angle 2°) was used during the measurements. To investigate the flow behavior of peanut butter, rheological analyses were performed at shear rates in the range of 0–10 s^{-1}. Rheological measurements were performed at 20°C.

2.3.2.pH

The pH values of the samples were determined using an Orion Star™ A211 model digital pH meter (Inolab, Weilheim, Germany).

2.3.3. Colour

A Konica Minolta brand colorimeter (Chroma Meter CR-400, Japan) was used to determine the color parameters (L*, a*, b*) of the samples. Color measurements were performed according to the CIELAB color system, and the samples were evaluated for L*, a*, and b* values. In this system, the L* value represents brightness (lightness-darkness), the a* value represents the red-green color axis, and the b* value represents the yellow-blue color axis (Bayarri et al., 2001).

2.3.4. Sensory

Peanut butters were evaluated for sensory evaluation of texture, oiliness, taste, fluidity, color, stickiness, and general impression. Sensory analyses were conducted by a group of nine trained panelists. Each panelist independently examined each sample and scored it using a 1 to 10 scale (1: very poor, 10: very good). Prior to the sensory assessment, the panelists were trained.

2.3.5. Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA), and group differences were identified using Duncan's multiple range test. Statistical analyses were performed using SPSS software version 18.0 (SPSS, Chicago, USA). In addition, nonlinear regression analysis was conducted to interpret the rheological data.

3.RESULTS AND DISCUSSION

3.1. Rheological Characteristics of Peanut Butter

The shear rate–shear stress relationship of the peanut butter samples was evaluated graphically, with the results presented in Figure 3.1. When the figures were examined, it was determined that the peanut butters exhibited non-Newtonian flow properties and showed pseudoplastic (shear thinning) flow behavior.

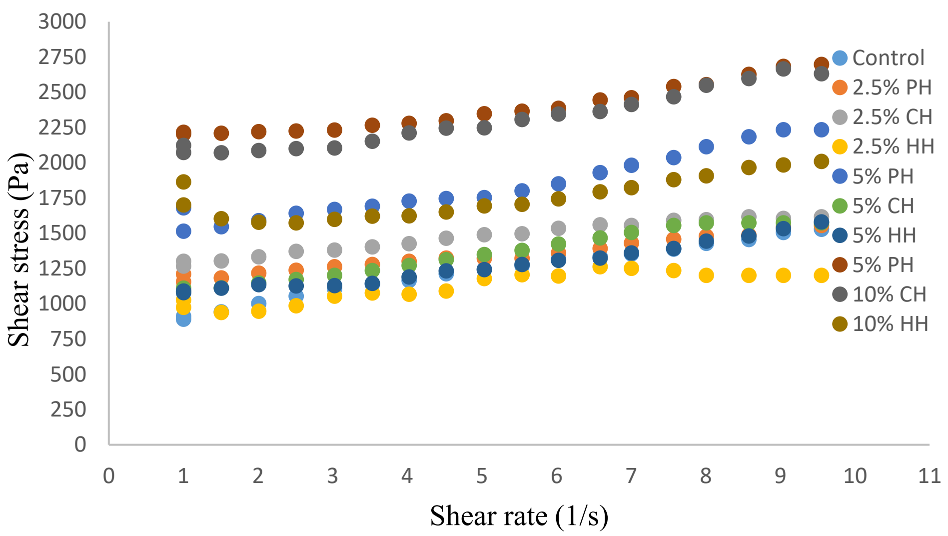

Figure 3.1. Variation of Shear Stress with Shear Rate in Peanut Butter (Pine honey (PH), Chestnut honey (CH) and Highland honey (HH)).

A study by Li et al. (2014) indicated that peanut butter shows non-Newtonian, pseudoplastic flow properties. Similarly, Sun and Gunasekaran (2009) also reported that peanut butter samples exhibited non-Newtonian pseudoplastic properties in their study. The rheological behavior of peanut butter described in previous studies is consistent with the results obtained in the present study. Data on the relationship between viscosity and shear rate in peanut butter containing different amounts of honey were evaluated graphically, and the results are shown in Figure 3.2. An examination of the graph revealed a decrease in viscosity values with increasing shear rate, confirming that the samples exhibited non-Newtonian pseudoplastic flow behavior. Furthermore, it was observed that viscosity increased with increasing honey amount added to the peanut butter. Among the honey types, pine honey (PH) had the greatest viscosity increase, while highland honey (HH) had the least. The greater viscosity increase in pine honey compared to other types of honey is thought to be due to its compositional differences due to its extraction from resinous pine secretion. According to Li et al. (2014), adding sorbitol to peanut butter reduced its viscosity, with higher sorbitol concentrations leading to greater decreases. Similarly, in a study conducted by Evcil (2022), a decrease in viscosity was observed in peanut butter produced by adding different amounts of apricot fiber as the amount of apricot fiber increased.

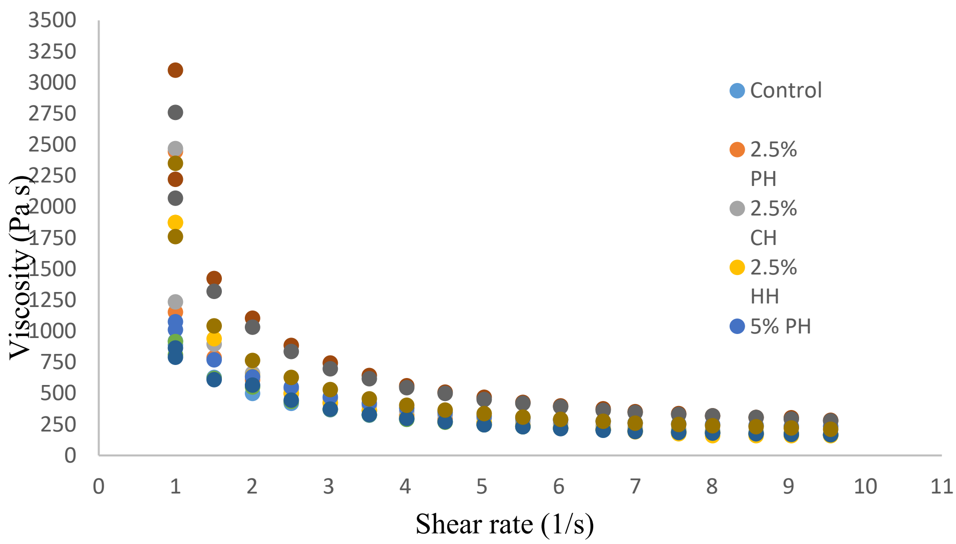

Figure 3.2. Viscosity-shear rate change graph of peanut butters (Pine honey (PH), Chestnut honey (CH) and Highland honey (HH)).

Table 3.1. Herschel-Bulkley model values of peanut butters

Peanut butters	τ_0 (Pa)	k (Pa·s^n)	n	R^2
Control	702	192	0.64	0.9988
PH %2.5	1176	14.79	1.44	0.9906
CH %2.5	1218	73.12	0.78	0.9522
HH %2.5	896	62.91	0.87	0.9186
PH %5	1569	5.41	2.14	0.9875
CH %5	1033	16.18	1.57	0.9978
HH %5	1091	7.33	1.86	0.9968
PH %10	2200	4.56	2.1	0.9966
CH %10	2065	10.14	1.83	0.9921

HH %10	1553	5.94	1.95	0.9937

Pine honey (PH), Chestnut honey (CH) and Highland honey (HH)

Since peanut butters produced with different proportions of honey addition exhibited non-Newtonian flow properties, rheological data were described using the Herschel-Bulkley model;

$$\tau = \tau 0 + K \gamma n$$

τ= Shear stress (Pa), τ0=yield stress according to Herschel-Bulkley (Pa), **k**= flow coefficient (Pa sn), **γ**= shear rate (1/s), n= flow behaviour index

The rheological behavior of peanut butter was characterized using the Herschel–Bulkley model, with the results summarized in Table 3.1. The R^2 values of the butters ranged from 0.9186 to 0.9978. Previous studies have also examined the rheological properties of peanut butter, describing its flow behavior using the Herschel–Bulkley model (Sun and Gunasekaran, 2009; Li et al., 2014; Tanrıkulu, 2022b). The results obtained in the present study are in agreement with these literature reports.

The spreadability of peanut butter depends primarily on the yield stress value. When the yield stress is high, the structure of the butter hardens and its spreadability decreases; a low yield stress increases fluidity and spreadability. In this study, an increase in the yield stress value was observed when honey was added to peanut butter and the amount of honey was increased.

Adding honey to peanut butter generally decreased the flow coefficient (k) and increased the flow index (n). This indicates that the pseudoplastic properties of the butters were enhanced and that their viscosity increased due to changes in particle arrangement and the formation of a network structure. Furthermore, honey types also affected the flow behavior of the butters. The flow coefficient values were determined according to the honey type in the order CH > HH > PH, while the flow index values were determined as PH > HH > CH. The honey that increased the viscosity of the butters the most was pine honey (PH), while the one that increased it the least was chestnut honey (CH).

In a rheological study conducted on peanut butter, it was determined that the flow behavior of the butters conformed to the Herschel-Bulkley model, and the flow index values were reported to range from 0.517–0.792 at 25°C and from 0.401–0.806 at 45°C. It was determined that the samples exhibited non-Newtonian, pseudoplastic flow properties (Taghizadeh and Razavi, 2009). In a study by Evcil and Bozdoğan (2025), the impact of incorporating varying levels of apricot fiber on the rheological behaviors of peanut butter was examined. The results indicated that higher concentrations of apricot fiber enhanced the fluidity of the butters while reducing their viscosity. Comparison of these literature findings with the current study revealed a consistent trend.

3.2. Sensory Evaluation of Peanut butters

Sensory evaluation results of Peanut butter are given in Table 3.2.

Table 3.2. Sensory evaluation results of peanut butter

	Oiliness	**Fluidity**	**Texture**	**Stickiness**	**Taste**	**Color**	**General impression**
Control	6.2±1^{b}	6.5±2^{b}	7.1±1^{b}	6.5±1^{c}	5.9±2^{c}	8.2±2^{b}	6.6±1^{c}
PH %2.5	6.4±1^{b}	6.7±2^{b}	7.5±1^{b}	7.0±1^{b}	7.4±1^{b}	8.2±2^{b}	7.0±1^{b}
PH %5	7.3±2^{ab}	8.0±1^{a}	8.2±1^{a}	7.8±1^{a}	7.8±1^{a}	8.5±2^{a}	7.8±1^{a}
PH %10	7.7±1^{a}	7.6±2^{ab}	8.0±1^{a}	7.3±2^{b}	8.1±1^{a}	8.1±2^{b}	7.8±1^{a}
CH %2.5	7.0±2^{ab}	6.5±2^{b}	7.4±2^{b}	7.2±2^{b}	7.4±2^{b}	8.0±2^{b}	7.3±2^{b}
CH %5	6.8±2^{b}	7.5±6^{ab}	7.8±2^{b}	7.4±1^{b}	7.4±1^{b}	7.0±1^{ab}	7.3±1^{b}
CH %10	6.3±2^{b}	6.4±6^{b}	7.1±2^{b}	7.2±1^{b}	7.0±2^{b}	8.0±2^{b}	7.0±2^{b}

HH %2.5	5.8±2^{c}	6.2±6^{b}	6.9±1^{b}	6.4±1^{c}	6.8±1^{bc}	8.1±2^{b}	6.3±1^{c}
HH %5	6.4±2^{b}	6.5±7^{b}	7.0±2^{b}	7.0±1^{b}	7.0±2^{b}	8.3±2^{b}	6.8±1^{c}
HH %10	6.8±2^{b}	7.7±8^{ab}	7.6±2^{b}	7.4±1^{b}	7.1±2^{b}	8.1±1^{b}	7.5±1^{b}

Pine honey (PH), Chestnut honey (CH) and Highland honey (HH)

As presented in Table 3.2, the samples exhibited statistically significant differences in taste, color, fluidity, oiliness, stickiness, texture, and overall acceptability ($p < 0.05$). The highest value in terms of oiliness was recorded in the sample with 10% PH added, followed by samples with 5% PH and 2.5% CH added. The highest values in terms of fluidity were obtained in the 5% PH, 10% PH and 5% CH samples, respectively. The highest scores in texture and taste criteria were obtained by the peanut butters containing 5% and 10% PH. The highest stickiness and taste scores were recorded in the samples containing 5% PH. The overall impression scores were highest in the samples with 5% and 10% PH, while the lowest scores were observed in samples containing 2.5% and 5% HH. In the literature, Bello et al. (2020) reported that the overall acceptability values of peanut butters with added preservatives ranged from 6.1 to 8.3. Similarly, Evcil (2022) determined that the overall acceptance level of butters produced with added apricots ranged from 5.3 to 7.3.

3.3. Color Characteristics of Peanut Butter

The L, a, and b color parameters of peanut butter were assessed, and the results are provided in Table 3.3.

Table 3.3. Color values of peanut butter

	L	**a**	**b**
Control	41.1±3.1^{bc}	3.9±0.1^{cde}	18.1±1^{bc}
PH %2.5	45.7±1.8^{a}	4.2±0.2^{bc}	19.5±0.4^{abc}
PH %5	39.9±1.9^{bc}	3.8±0.1^{e}	17.6±0.7^{c}
PH %10	41.2±3.2^{bc}	4.3±0.2^{b}	18.4±1.4^{bc}
CH %2.5	43.1±0.6^{ab}	4.3±0.2^{b}	19.7±0.2^{ab}
CH %5	43.6±0.9^{ab}	4.5±0.1^{a}	20.5±0.6^{a}
CH %10	38.7±1.1^{c}	4.1±0.1^{bcd}	18.1±0.5^{bc}
HH %2.5	38.9±2^{c}	3.9±0.1^{de}	17.7±1.1^{c}
HH %5	41.8±2.9^{abc}	4.2±0.1^{bc}	19.0±1.8^{abc}
HH %10	40.7±1.6^{bc}	4.1±0.2^{bcd}	18.6±1.2^{abc}

Pine honey (PH), Chestnut honey (CH) and Highland honey (HH)

Statistically significant differences ($p < 0.05$) were found among the peanut butter samples in terms of their color parameters (L, a, b). The highest L* value was recorded in the samples containing 2.5% PH. The control sample exhibited the lowest a value, whereas the highest a value was recorded in the peanut butter containing 5% CH. The addition of honey resulted in an increase in reddish tones. Regarding b values, the maximum was observed in the 5% CH sample, whereas the minimum values were found in samples with 2.5% PH.

4. CONCLUSION

The impact of incorporating varying levels (2.5%, 5%, and 10%) of pine honey (PH), chestnut honey (CH), and highland honey (HH) on the rheological, and sensory characteristics of peanut butter was examined. Rheological analysis indicated that all peanut butter samples exhibited non-Newtonian, pseudoplastic flow behavior, which was well described by the Herschel-Bulkley model. Significant differences were observed among the samples in sensory attributes, including color, fluidity, texture, oiliness, stickiness, taste, and overall impression ($p < 0.05$). The sample containing 5% PH received the highest score from panelists, followed by the 10% CH sample. Based on these findings, the addition of 5% PH is recommended for peanut butter production.

The superior sensory acceptance observed with the incorporation of 5% pine honey indicates that this formulation can enhance consumer preference without necessitating major modifications to existing production processes. Moreover, employing honey as a natural sweetening agent eliminates the need for refined sugar addition, thereby supporting the development of more natural, value-added products and offering a competitive advantage for the food industry.

Future research is recommended to further investigate the effects of different honey types and addition rates on the chemical and rheological properties of peanut butter. Monitoring rheological behavior under different temperatures and storage conditions and optimizing flow properties will also be beneficial for further research.

DECLARATION OF CONFLICTING INTERESTS

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