

Physical properties of different nut butters

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ABSTRACT

The objective of our work was to analyze the differences between four nut pastes, which were the following: walnut, peanut, pistachio, and tahini (sesame). The process technology of them is unknown, however, all the products contain 100% nut without any additives or flavoring.

The paste samples were measured at 25 ± 0.2 °C. The apparent viscosity at a 10 1/s shear rate during flow curve recording, and the dynamic viscosity at a constant 20 1/s shear rate was determined by viscosity measurement with the use of the MCR302 modular compact rheometer. The $L^*a^*b^*$ color components were determined by ColorLite sph850 spectrometer, finally, the particle sizes and shapes of the samples were analyzed by the high-speed image analysis instrument QICPIC.

The apparent viscosity and the average dynamic viscosity values of the four nut pastes were significantly different from each other. Differences were found between each paste according to the $L^*a^*b^*$ parameters. The complex structures of the particles are detailed and measurable, whereby the lengths and diameters of the particles can reliably be determined and fine deviations between the samples are detected. The sphericity decreases slightly with increasing particle size which means that bigger particles are more irregularly shaped.

KEYWORDS

viscosity, color, particle size, paste, nuts

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INTRODUCTION

In recent years, tree nuts have become more popular as consumer demand for healthy diet has increased. Brazil nut, almond, cashew, hazelnut, macadamia, pecan, pine nut, pistachio, and walnut are the most popular nuts in the world. Nuts and seeds are nutrient-dense foods, and they are commonly consumed as whole nuts/seeds or in a processed form for example nut butters and seed butters, or used as ingredients in other processed foods, particularly in spreads, bakery, and confectionary products (Shakerardekani et al., 2013a).

Due to new developments, a wide range of nut and seed-based products are available of which butters and spreads become increasingly popular. The expression plant-based butter made from nut or seed describes a product with at least 90% nut/seed content, while the expression spread is used to a product containing at least 40% nut/seed, which can be added in various forms, e.g., as nuts, a paste and/or a sludge (Wilkes, 2012). Increasing consumer awareness of plant-based butters has led to the development of various nut and seed types of butter. These spreadable plant-based butters are a great source of fiber, proteins, essential fatty acids, and other nutrients (Shakerardekani et al., 2019). In addition to their good nutritional value, nuts have a widely accepted taste, so they can be eaten on their own or in combination with other foods. Nut and seed spreads are great options for a healthy vegetarian or vegan breakfast and snack. For those companies selling different types of nut butters, it is important to consider that Plasek et al. (2021) found that it is market relevant that palm oil free products communicate this characteristic to consumers, as it provides an opportunity to reduce the negative feelings about palm oil so that these products can be positioned as healthier foods.

Both spreadable products are made from nuts ground into a paste. The production technology is a two steps size reduction process. The first step is grinding using typical grinding machines like colloid mills, attrition mills, disintegrators, and hammer mills and the second step is homogenizing (Rozalli et al., 2015). The process of grinding affects the quality of the nut butter as it defines its particle size, consistency, and viscosity which also influences its physical, textural, and organoleptic features (Norazatul Hanim et al., 2015). Shakerardekani et al. (2019) found that the raw kernel quality, roasting temperature, and time also affect the quality of the final product.

For product development, it is essential to know the rheological data of the nut butter that determines the texture, sensory properties, and engineering requirements for processing equipment. Furthermore, the rheological properties (e.g., viscosity) also affect other steps in the manufacturing technology such as transporting by pumps or packaging (Wilkes, 2012; Kovács et al., 2021).

The aim of our work was to identify the viscosity, color, and particle sizes of different types of nut butter.

MATERIALS AND METHODS

Nut butter samples

In our experiment same brand, commercially available, 4 different types of nut butter pistachio, walnut, peanut, and tahini were analyzed. The samples were stored at room temperature and homogenized by manual mixing after opening for measurement. In this way, the nut butter, which settled naturally during storage, was mixed with the nut oil appearing on the surface of the samples.



Viscosity

The flow curve of nut paste samples was measured with MCR302 modular compact rheometer (Anton Paar, Austria) in parallel plate geometry (PP50) by Rheo Compass software at room temperature (25 ± 0.2 °C) with three replicates by sample type. During the rotational test with controlled shear rate, the measurement consisted of two stages: first of all, increasing the shear rate from 0.0 1/s to 20 1/s. The data recording was reduced with a linear scale from 5 to 1 s, and 60 data were recorded during 180 s. In the second stage, the shear rate was constant at 20 1/s for 60 s, and 60 points were recorded. The apparent viscosity at 10 1/s on the flow curve and the viscosity were determined at a 20 1/s shear rate in the constant stage. The apparent viscosity and dynamic viscosity values of the samples were determined by Rheo Compass software (Anton Paar, Austria).

Color

The CIELAB L^* , a^* and b^* color coordinates were determined with ColorLite sph850 spectrophotometer (ColorLite, Germany). The surface color of all samples was measured with three replicates.

Particle sizes and shapes

The particle sizes and form parameters (aspect ratio and sphericity) of the samples were analyzed by high-speed image analysis instrument QICPIC (Sympatec GmbH, Germany). The pastes contained coarse particles; however, their numbers were not high. Therefore, with two sampling both samples were measured three times. Finally, the average of the six measurements were evaluated. The nomenclature of the measurement results is in accordance with ISO 9276. The following measuring ranges were selected for the analysis (Table 1).

The settings during the measurement were as the following (Table 2).

For the evaluation of the measured data the following were used: the calculation modes EQPC (diameter of the circle of equal area), FERET_MAX (maximum diameter over all measuring direction), FERET_MIN (minimum diameter over all measuring direction). The form characteristics of the particles are described by aspect ratio (f_{ar}) and sphericity (f_{sph}). The aspect ratio is defined as the ratio of the FERET_MIN and FERET_MAX. Sphericity is the ratio of the perimeter of the equivalent circle P_{EQPC} to the real perimeter P_{real} . The result is a value between 0 and 1. As this value decreases, the irregularity of the particle increases. This is due to the fact that the irregular shape has an effect on the growth of the perimeter. In addition to the listed parameters, the cumulative distribution for volume (Q_{volume}) was also determined, which indicates the normalized fraction of particles that are smaller than the particle diameter.

Statistics

Viscosity and color data were analyzed by one-way analysis of variance (one-way ANOVA) with using of IBM SPSS 27 software (IBM, USA), and $P < 0.05$ was considered statistically significant. To determine where the significant differences were, Tukey HSD post-hoc test was used after normality and standard deviation homogeneity test.



Table 1. Selected measuring ranges; physical limits (lower limit corresponds to the pixel size – upper limit results from number of pixel and size of form); evaluation limits according to ISO 13322-2

Measuring range	Physical limits/ μm	ISO limits/ μm
M5	1.8–3,755	1.8–1,252
M7	4.2–8,665	4.2–2,888

Table 2. Settings of the measurements

Parameters	Pistachio	Walnut	Peanut	Tahini
Amount of sample	0.50 g	0.50 g	0.50 g	0.50 g
Measuring range	M5	M5	M7	M7
Dispersing liquid	rape oil	rape oil	rape oil	rape oil
Stirrer speed	200 rpm	200 rpm	200 rpm	200 rpm
Pump speed	100 rpm	100 rpm	100 rpm	100 rpm
Measuring time	120 s	120 s	120 s	120 s
Pieces of measured particle	20 pcs <30 μm 16 pcs >30 μm	20 pcs <30 μm 16 pcs >30 μm	20 pcs <60 μm 16 pcs >60 μm	20 pcs <60 μm 16 pcs >60 μm

RESULTS AND DISCUSSION

Viscosity

The aim of the experiment was not to model the flow curves, however the recorded flow curves mostly showed a non-Newtonian behavior, although, in the case of nut cream, it seems more like a Newtonian behavior due to the linear flow curve. Flowing such materials in a pipe is easier and more cost-efficient because the energy required for fluid flow depends on the shear stress occurring in the pipe system, which affects the viscosity (Csurka et al., 2020).

Despite the low maximum shear rate (20 1/s), inhomogeneous behavior was found in the case of the tahini butter. The pistachio and peanut butter samples showed similar behavior, but the system become unstable above 15 1/s. The particles were rearranged, they stood into the shearing direction, but they still started drifting out from under the measuring head. The flow curve with the lowest slope was shown by the nut cream (Fig. 1).

The apparent viscosity was determined at shear rate of 10 1/s. The Table 3 shows that the highest standard deviation has the peanut butter samples, and the walnut has the lowest one. The sequence of butter samples based on the apparent viscosity values is consistent with the shear stress values of the yield curves.

The dynamic viscosity and its decrease were determined at constant maximum shear rate as well. The highest viscosity showed the pistachio and sample with lowest viscosity was the walnut. A phenomenon of decreasing viscosity was observed at constant shear rate and refers to the phenomenon of thixotropy in the case of all the measured samples. Çiftçi et al. (2008) found that at constant shear rate, the sesame paste exhibited thixotropic behavior, as Norazatul Hanim et al. (2015) reported a similar result for peanut paste. Covaliov et al. (2022) in a storage experiment with nut cream found that the apparent viscosity decreased proportionally with storage time. Considering their results, the apparent viscosity value of the



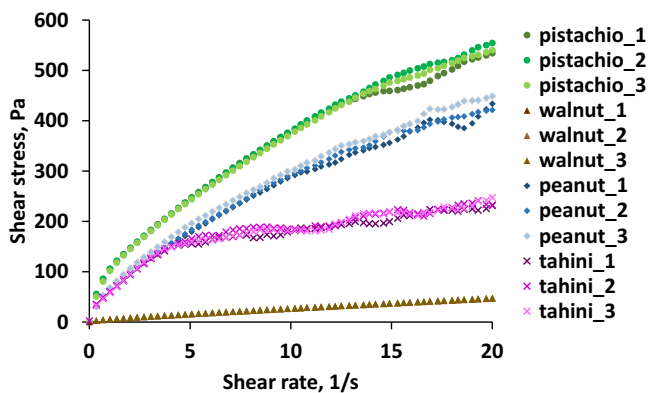


Fig. 1. Flow curves of the measured types of nut butter

Table 3. The average \pm standard deviation values of apparent viscosity, dynamic viscosity and decrease of dynamic viscosity

	Apparent viscosity at 10 1/s shear rate (mPas)	Average dynamic viscosity at 20 1/s shear rate (mPas)	Decrease of the dynamic viscosity at 20 1/s shear rate (mPas)
Pistachio	37,777 \pm 339.4	24,763 \pm 612.0	4,364.7 \pm 370.3
Walnut	2,704 \pm 30.27	2,365.5 \pm 27.85	18.13 \pm 1.193
Peanut	29,452 \pm 629.6	17,757 \pm 466.0	6,720 \pm 81.5
Tahini	18,266 \pm 248.6	9,956 \pm 289.5	3,720.6 \pm 961.8

commercially available nut cream we studied, determined at a shear rate of 10 1/s, may correspond to a seed paste stored for several months.

It is important to know the physical and rheological properties of nut butters made from 100% nuts/seeds, as all the other ingredients affect the properties of the butter. [Shahidi-Noghabi et al. \(2018\)](#) investigated the effect of different amounts of emulsifiers on walnut butter and found that emulsifier dosage affected droplet size, viscosity and thixotropy. [Shakerardekani et al. \(2013b\)](#) found significant differences in the physicochemical and rheological properties of pistachio spreads after the addition of monoglycerides as one of the lipophilic emulsifiers. It affected the spreadability, consistency, viscoelastic properties, flow behavior and dynamic oscillation measurements of the spreads.

Color

The CIE L^{*}a^{*}b^{*} color parameter values of the nut butters were close to each other, however, the a^{*} value of tahini was negative. The lightness (L^{*}) values were between 35 and 55. [Figure 2](#) combined with [Table 4](#) shows the three replicates' results.

Significant different was found between the different types of nut butter in the case of the viscosity and color measurement parameters based on the ANOVA results.



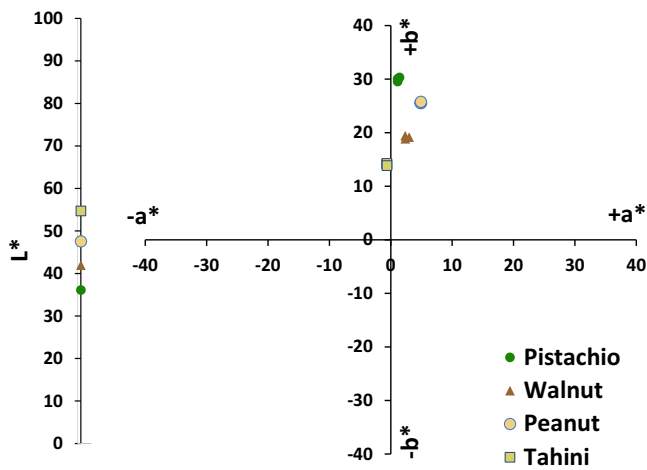


Fig. 2. CIE Lab results of the nut butters

Table 4. The average \pm standard deviation values of CIE Lab color parameters

	L^*	a^*	b^*
Pistachio	36.72 ± 0.6101	1.220 ± 0.1819	29.98 ± 0.4038
Walnut	41.38 ± 0.7158	2.567 ± 0.3667	19.16 ± 0.2902
Peanut	47.54 ± 0.06658	4.880 ± 0.05568	25.63 ± 0.1210
Tahini	54.49 ± 0.2914	-0.633 ± 0.01528	14.09 ± 0.2066

Particle size

Beside the rheology and color measurements, the particle size distribution for volume (Q_v), the EQPC, the FERET_MIN and FERET_MAX diameters, furthermore, the aspect ratio and sphericity as form parameters were determined. Figure 3 illustrates the average Q_v results in % in the case of the nut butters. The EQPC results show that the behavior of the tahini is different from

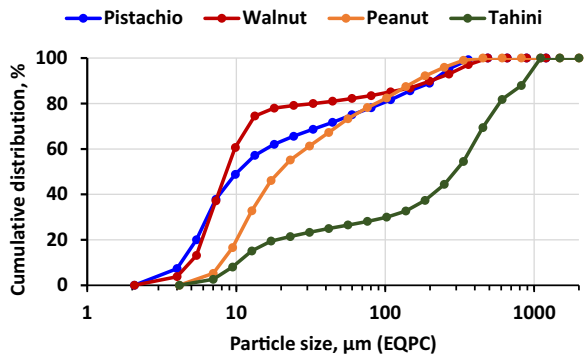


Fig. 3. Cumulative particle size distribution curves in % (EQPC)



the others, it has more particles with bigger sizes. Çiftçi et al. (2008) also found a large particle size in sesame paste measurements. They found that this negatively affected colloidal stability.

The results of the FERET_MAX and FERET_MIN particle sizes are shown by Fig. 4. The result of EQPC was confirmed by the results of FERET_MAX and FERET_MIN diameters.

Differences were found between the aspect ratio of different types of nut butter (Fig. 5). The tahini aspect ratio value was lower from the others, and it showed biggest particle size based on the measured sample amount.

The sphericity of the particles of the different types of nut butter showed a difference. The sphericity of the walnut and pistachio samples was almost similar; however, the particle size of the peanut and tahini was bigger, and the tahini particles were less rounded than the other nut

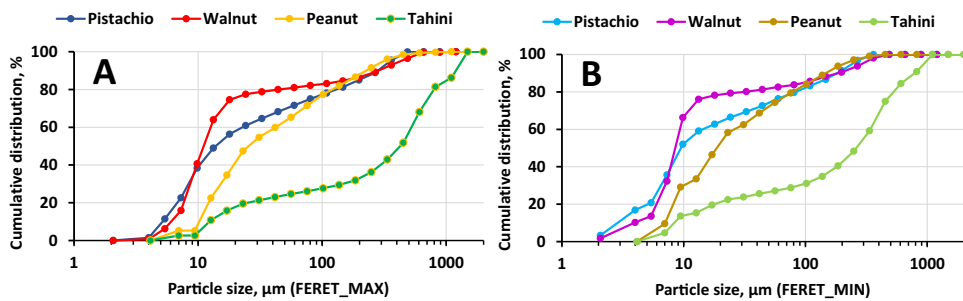


Fig. 4. Cumulative particle size distribution curves in % (FERET_MAX (A) and FERET_MIN (B))

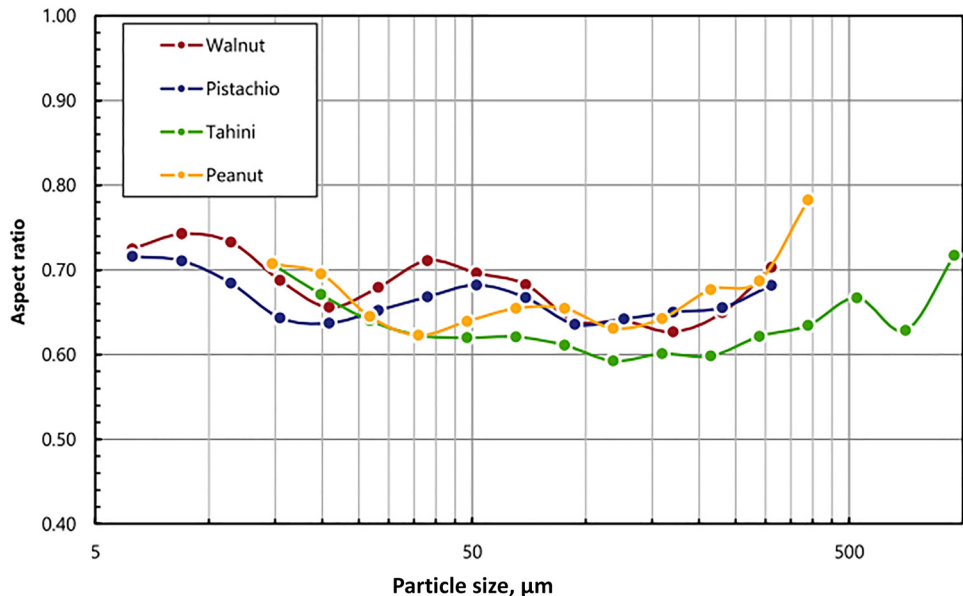


Fig. 5. The aspect ratio over particle size (EQPC)



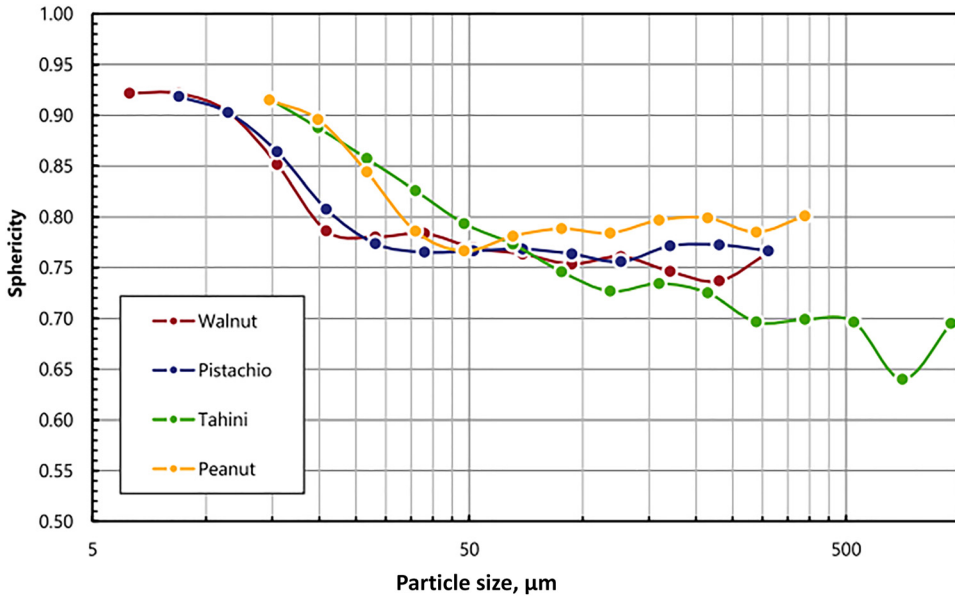


Fig. 6. The sphericity over particle size (EQPC)

butter particle. Based on the results, the sphericity decreases with the particle size increasing. Citerne et al. (2001), in their study of commercial peanut butters, found that non-colloidal peanut grains in peanut oil and large grains make the structure of the samples unstable and affect their rheological properties (e.g. viscosity, smoothness) (Fig. 6).

Norazatul Hanim et al. (2015) observed variety-dependent particle size in paste preparing when studying pastes made from different varieties of peanuts and their results showed that the yield strength of the paste affected the spreadability. Shakerardekani (2014) investigated the relationship between the grain size of pistachio paste and its structural stability and claimed that larger grain size impairs stability. However, he also performed model fitting on the flow curves in addition to viscosity.

CONCLUSION

This aim of this work was to compare the physical properties of different nut butters by the viscosity-, color- and particle size measurement. The process technology of the analyzed pistachio, walnut, peanut, and tahini pastes is unknown; however, all the products contain 100% nut without any additives or flavoring.

The apparent viscosity and the average dynamic viscosity values of the four nut pastes were significantly different from each other. The results were confirmed by ANOVA as well. The decreasing viscosity at a constant shear rate refers to the phenomenon of thixotropy. Significant differences were found between the different nut butters in the case of the CIE L^* , a^* , and b^* measurement parameters.



The particle size distribution for volume (Q_v), the EQPC, the FERET_MIN and FERET_MAX diameters, furthermore, the aspect ratio and sphericity as form parameters were determined. The EQPC results show that the behavior of tahini is different from the others, it has more particles with bigger sizes. A difference was found between the aspect ratio of nut butters. The tahini aspect ratio value was lower than the others, and it showed the biggest particle size based on the measured sample amount. The sphericity of the particles of the different nut pastes showed a difference. The sphericity of the walnut and pistachio samples was almost similar; however, the particle size of the peanut and tahini was bigger, and the tahini particles were less rounded than the other nut butter particle. Based on the results the sphericity decreased with the particle size increasing.

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