Rheological properties of starch-milk-based dessert creams with sunflower, almond and hazelnut tahini

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Abstract. The influence of the type and quantity of added tahini in the composition of starch-milk dessert cream on the rheological and thixotropic properties was analyzed. Three types (sunflower, almond and hazelnut) and quantity (3, 6 and 12%) of tahini were used. After the analysis, it was found that the cream with 3% almond tahini had the highest viscosity, and the cream with 12% almond tahini had the lowest viscosity. All samples showed a non-Newtonian character, which is mainly due to the starch in their composition. In terms of thixotropic properties, the cream with 12% almond tahini showed the highest resistance, and the cream with 3% sunflower tahini showed the lowest resistance. The obtained results could be used when implementing similar types of products in food production.

1 Introduction

Dessert creams are widely used in the food industry, both individually and as a filling for various foods or for handling surfaces of sweet products. They shape the appearance, taste and colour of many desserts causing pleasant visual, smell and taste sensations [1]. Dessert creams have relatively high nutritional value due to the high content of starch and sucrose [2].

These products rheological and sensory properties are very significant in terms of industrial, consumer acceptance, and nutritive profile. Food rheology parameters are directly related to the acceptance of the final product by consumers. However, the food's rheological behaviour, such as dairy products, can be influenced by some factors such as food processing, product stability, and organoleptic properties. For these reasons, food rheology is an important analytical tool to evaluate food quality. These products` rheological and textural properties are very important in terms of industrial manufacturing, consumer acceptance, and nutritive characteristics [3, 4]. In general, this type of product shows time-dependent and shear-thinning flow behavior, and viscoelastic properties typical for weak gels. However, noticeable differences in rheological properties can be found in model systems with different compositions [5, 6]. When new components or their combinations are incorporated into products, the effect of such modification on rheological and textural properties should be researched [4].

Tahini is widely known as one of the natural health-promoting foods that can potentially prevent various health problems such as hypertension, hypercholesterolemia, cancer and ageing. Additionally, it may be useful in managing oxidative stress-associated diseases, such as atherosclerosis, diabetes mellitus, obesity, chronic renal failure, rheumatoid arthritis, and neurodegenerative diseases including Alzheimer's disease [7, 8].

Traditionally, tahini is made from sesame seeds, but in Eastern European countries sesame is replaced with sunflower seed kernels due to their accessibility in this geographical region and economic reasons [9]. Another advantage of using sunflower kernels is that they do not contain allergens, so their use is a viable alternative in confectionery. Sunflower tahini can be used as an alternative to obtain various pastes from expensive oleaginous kernels (e.g., pistachio, hazelnut, almond, etc.), which in turn are used in the production of different products [10]. Recently, tahini has been commercialized as an individual product, thus its quality and colloidal stability should be manipulated to maintain its properties as desired by consumers and it can be used as a condiment, dressing, spread, sauce and mixture with different fruit syrups [11]. Pseudoplastic behavior was observed in sunflower tahini, regardless of the temperature and particle size studied. Rheological analysis revealed a higher thixotropic degree of the coarser sunflower tahini samples. Rheological properties characteristic of a viscoelastic material were observed,

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with a dynamic frequency response typical of weak gels [10].

Due to the interest in this type of product, the purpose of the present work was formulated. For the evaluation, it is necessary to establish and compare the rheological and thixotropic properties of starch-milk-based dessert creams with different types and contents of tahini.

2 Materials and methods

2.1 Materials

All materials were from the local market. Table 1 shows the nutritional composition of the three tahini.

Table 1. Nutritional composition of tahini

Nutritional information for 100 g product	Hazelnut tahini	Almond tahini	Sunflower tahini
Energy:	2600 kJ/ 621 kcal	2765 kJ/ 661 kcal	2370 kJ/ 566 kcal
Fats from which saturated fatty acids:	62g 7g	54g 6g	65g 10g
Carbohydrates from which sugars:	17g 4g	20g 4g	13g 3g
Proteins:	15g	24g	17.5g
Salt:	0g	0g	0g

2.2 Methods

2.2.1 Obtaining a starch-milk based dessert creams

Starch-milk-based dessert creams with tahini are prepared in laboratory conditions. First, the dry ingredients are weighed – rice starch (7.9%), milk powder (10.25%) and sugar (13.4%). They are homogenized and the pre-weighed water (to 100%) is added in small portions. The mixture thus prepared is heated to a temperature of 80±2°C, with continuous stirring, and boiled until the dry matter ~ 31%. The cooked starch-milk-based dessert creams are cooled to a temperature of 60±2°C and the weighed amount of three different concentrations (3, 6, 12 % to the weight of the cream) of three types (sunflower, almond and hazelnut) of tahini. The tahini complements the flavor profile of the product and gives it additional aromatic properties. The tahini is added to the cream, homogenized and analysed.

2.2.2 Rheological and thixotropic properties

Rheological characteristics were determined using a Rheotest-2 rotational viscometer (Rheotest Medingen GmbH, Medingen, Germany), operating at 50°C within the shear rate range from 0.17 to 72.9 s^{-1}. The dynamic viscosity (η) was calculated using the formula:

$$\eta = \frac{\tau}{D} \qquad (1)$$

Where τ is the shear stress, Pa; D is the shear rate, s^{-1}.

$$\tau = \tau_0 + k.D^n \qquad (2)$$

Where τ_0 - is the yield stress, Pa ; k – is the consistency coefficient, Pa.s; n – is the flow behavior index.

Thixotropic properties of the starch-milk creams with tahini were determined by their flow curves (with coordinates D/τ). The thixotropic areas, S_{th}, were obtained as the difference between the area enclosed by the up curve, S_{up}, and the area enclosed by the different down curves, S_{dw}, in the shear rate range considered.

$$S_{th} = S_{up} - S_{dw} \qquad (3)$$

These areas could be calculated by numerical integration or analytical integration if the function relating shear stress and shear rate, τ = f (D).

$$S = \int_{D_{min}}^{D_{max}} \tau(D) dD \qquad (4)$$

2.2.3 Data analysis

The analyses were performed three times. All results were expressed as the mean ±standard deviation (SD).

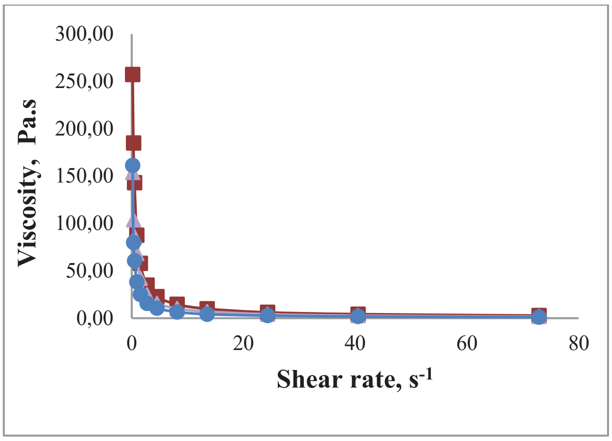
3 Results and discussion

3.1 Analysis of the rheological and thixotropic properties of starch-milk based dessert creams with tahini

The rheological behavior and thixotropic properties of starch-milk based dessert creams with three types tahini were analyzed at a temperature of 50°C. Rheograms of the analyzed samples were constructed, respectively for each type of tahini with different percentage content (dark colored for upward curve and light for downward curve).

3.1.1 Starch-milk based dessert creams with hazelnut tahini

Viscosity is defined as the main rheological parameter, which represents a fluid's internal friction or tendency to resist flow, also studied by other authors [3].



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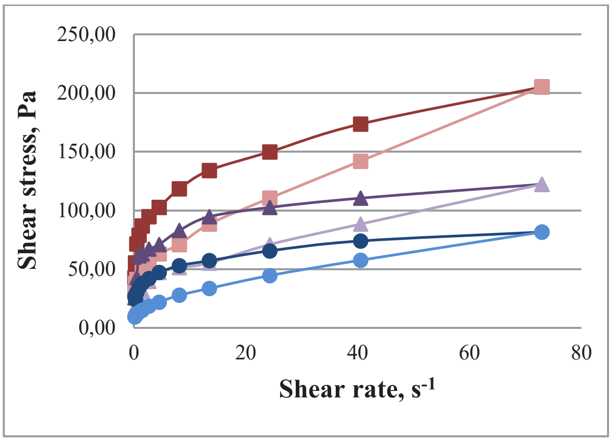


B)

Figure 1. Viscosity (A) and rheograms (B) of starch-milk cream with hazelnut tahini 3% (□), 6% (Δ), 12 % (○)

Figure 1 (A) shows the viscosity of starch-milk cream with different percentages of hazelnut tahini as a function of shear rate (D). It is evident from the data that as the shear rate value increases, the viscosities decrease. When changing D in the low value range for a small interval, the relative decrease in viscosity is greater than in the high D value range for a long interval. The close values of the relative decrease in viscosities show that the degree of changes in the structures of the individual systems is close.

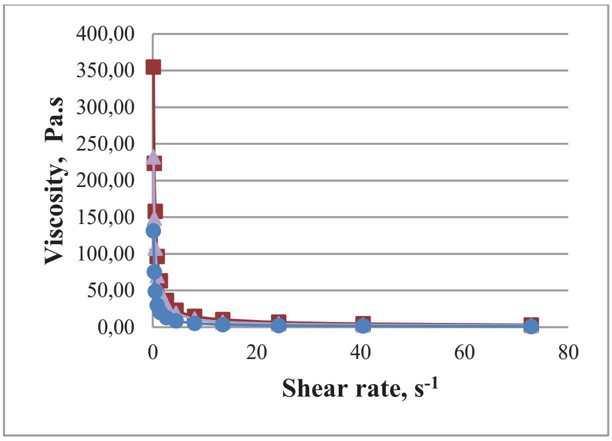
With the smallest changes in viscosity when changing the velocity gradient according to the data in Figure 1 is the cream with 12% tahini content, because its start and end points of change are the least apart from the other two creams, which means that it underwent minor changes as the velocity gradient increased. Slightly different from it is the cream with 6% hazelnut tahini content, and the cream with 3% tahini content undergoes the biggest changes.

The relation between the tangential stress (τ) and the velocity gradient (D) for a hazelnut tahini starch cream is presented graphically in Figure 1 (B). It is noteworthy that the different concentration of tahini has a great influence on the structure of the cream under mechanical impact.

The cream with 3% hazelnut tahini content exhibits the highest values of thixotropic properties, which is due to the increased destruction of the system structure with increasing stress. The one with 12% hazelnut tahini content exhibits stability under increasing loads and speed of mechanical impacts, meaning it does not easily yield to changes. These results are also confirmed by the results presented in Table 2.

3.1.2 Starch-milk based dessert creams with almond tahini

Figure 2 (A) shows the viscosity of starch-milk cream with different percentages of almond tahini depending on the velocity gradient (D).



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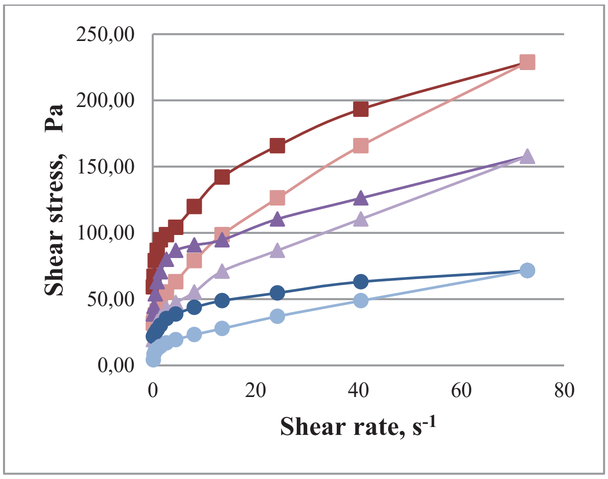


B)

Figure 2. Viscosity (A) and rheograms (B) of starch-milk cream with almond tahini 3% (□), 6% (Δ), 12 % (○)

The obtained data presented in Figure 2 (A) repeat the dependence that was reported for the cream obtained with hazelnut tahini. It can also be seen here that as the value of the velocity gradient increases, the viscosities decrease. The close values of the relative decrease in viscosities show that the degree of changes in the structures of the individual systems is close.

With the smallest changes in viscosity when changing the velocity gradient according to Figure 2 (A) is the cream with 12%, followed by that with 6%. Here the difference in initial viscosity is clear. With the biggest changes in viscosity, the cream with 3% tahini stands out again.

From the graphically expressed relationship between tangential stress (τ) and velocity gradient (D), it is evident that both hazelnut and almond tahini affect the base starch-milk dessert cream. Any change in the quantitative content of tahini gives the cream a different degree of structural destruction under mechanical impact.

The cream with 3% content of almond tahini exhibits the highest values of thixotropic properties, which is due to the increased destruction of the structure of the system with increasing tension. The stability of the system increases in direct proportion to the amount of tahini added (Table 2).

3.1.3 Starch-milk based dessert creams with sunflower tahini

Figure 3 (A) shows the viscosity of starch milk cream with different percentages of sunflower tahini as a function of the velocity gradient (D).

According to Figure 3 (A), cream with 6% tahini has the smallest change in viscosity. The results are close to sample with 3% tahini content. The highest viscosity has the sample with 12% tahini. This shows that the higher amount of sunflower tahini added affects viscosity and stability, this can be explained by the higher viscosity of this tahini compared to the previous two.

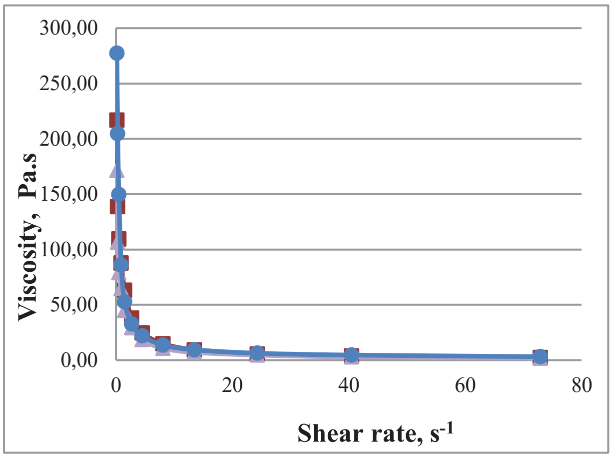
Figure 3 (B) shows the graphically expressed relationship between the tangential stress (τ) and the velocity gradient (D) applied to starch cream with sunflower tahini. As with other creams with hazelnut and almond tahini, the different concentration of the tahini has an effect on the structure of the cream under mechanical impact.

The reason for the dependence between increasing stability with higher amount of used tahini could be the coarseness of the ground nut particles. Similar results were obtained in the preparation of halva with sunflower tahini [12].

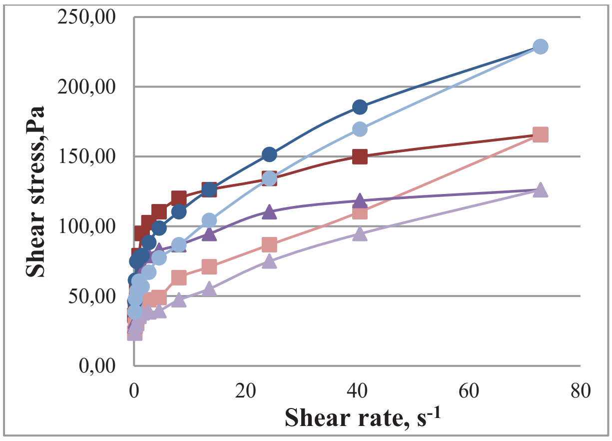
The flow curves for all systems present narrow hysteresis loops, indicating changes in the structure of the samples under the applied shear [13].

The parameters of the power law model for the samples are given in Table 2, along with the correlation coefficient (R^2). The coefficients of determination, R^2, shown in Table 2 reported a very good suitable to the Herschel-Bulkley model, which is widely used in the analysis of various food systems [14, 15].

The coefficients of determination (R^2) obtained are high and range from 0.9070±0.023 to 0.9837±0.148, typical of Herschel-Bulkley models.



A)



B)

Figure 3. Viscosity (A) and rheograms (B) of starch-milk cream with sunflower tahini 3% (□), 6% (Δ), 12 % (○)

The consistency factor (k) and flow behaviour index (n) obtained by fitting the power law and Herschel-Bulkley models to the experimental shear stress-shear rate data are given in Table 2. The yield stress is an important characteristic indicating the stress at which a material will begin to deform plastically. High values of the yield strength, τ_0, from the Herschel-Bulkley model indicate high structural stability of the samples [16]. The power law equation was found to be an adequate model to describe the flow behaviour of the samples in this study. Viscosity function data indicate that all systems studied are non-Newtonian fluids, as values for the flow behaviour indices, n, are below 1, indicative of pseudoplastic (shear-thinning) character. Yield stress fluids from a particular state of matter, displaying non-linear and novel visco-plastic-elastic flow dynamics upon different boundary conditions. They don't flow until a certain load, the so-called yield stress (or point, τ_0), is applied. This value may be generally interpreted as a shear stress threshold for the breakage of interparticle connectivity. The yield strength (τ_0) of the samples is from

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Table 2. Parameters of Herschel–Bulkley models for flow curves of the starchy-milk creams with hazelnut, almond and sunflower tahini (3, 6, 12 %)

Type of tahini	Quantity, %	τ_0	k	n	R^2	τ_0	k	n	R^2	Hysteresis loop area, Pa. s^{-1}
		Upward curve				Downward curve				
Hazelnut	3	38.70±0.77	74.69±1.34	0.231±0.003	0.9800±0.0147	28.00±0.42	45.61±0.68	0.288±0.004	0.9460±0.0142	3037.68±45.60
	6	22.80±0.68	48.24±0.48	0.242±0.003	0.9395±0.0281	12.50±0.375	30.78±0.92	0.268±0.008	0.9219±0.0277	2426.99±72.81
	12	16.00±0.24	34.70±0.52	0.199±0.003	0,9837±0.0148	8.00±0.12	14.73±0.22	0.348±0.005	0.9713±0.0146	1413.05±21.20
Almond	3	56.00±1.12	88.79±1.15	0.191±0.004	0.9452±0.0189	38.70±0.774	47.32±0.95	0.307±0.006	0.9272±0.0185	2494.80±49.90
	6	34.50±0.69	60.05±1.20	0.208±0.004	0.9770±0.0195	17.00±0.34	33.52±0.67	0.311±0.007	0.9721±0.0200	1754.19±35.00
	12	22.00±0.33	29.12±0.67	0.199±0.003	0.9699±0.0145	2.00±0.03	11.523±0.1728	0.389±0.006	0.9630±0.0144	955.02±14.33
Sunflower	3	32.80±0.66	67.96±1.29	0.240±0.005	0.9070±0.023	21.50±0.43	36.84±1.09	0.290±0.001	0.9643±0.0020	3935.12±23.50
	6	26.70±0.67	51.10±0.82	0.245±0.004	0.9324±0.001	19.00±0.02	34.24±0.05	0.244±0.002	0.9179±0.0135	2854.56±35.65
	12	44.00±0.88	75.60±1.12	0.228±0.003	0.9609±0.005	32.60±1.02	58.46±0.57	0.264±0.001	0.9446±0.0234	1463.57±22.36

When comparing the three concentrations and the three types of tahini, it is evident that as the percentage of tahini increases, so does the stability of the system. The highest values of thixotropic properties are exhibited by the cream with a content of 3% sunflower tahini, which is due to the increased destruction of the structure of the system with increasing tension. The one with 12% content of almond tahini exhibits the greatest resistance to increasing tension and the degree of mechanical impact.

All tested samples showed shear softening behaviour as is obvious in rheograme while showing a decrease in viscosities at increasing shear rate. Similar relations in the rheological behaviour of pastry creams have already been reported [17].

Table 2 presented areas of hysteresis loop of the the starchy-milk creams with hazelnut, almond and sunflower tahini (3, 6, 12 %). When increasing the amount of tahini, a decrease in thixotropic properties is noticed. This means that increasing the tahini percentage also increases the stability of the cream. With the highest value of thixotropy is the sample with 3% sunflower tahini (3935.12±23.50), and with the lowest the cream with 12% almond tahini (955.02±14.33).

4 Conclusion

The present study showed that the addition of tahini in the formulation of starch-milk based dessert creams with increasing amount of tahini reduced the viscosity, except 12% sunflower tahini and increased the stability in terms of thixotropic properties of the resulting creams with all three types of tahini. The sample with 3% sunflower tahini had the highest viscosity, and the one with 12% almond had the lowest viscosity and the highest stability. Future research can also be done on sensory characteristics as an important indicator.

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