

Improving Sunflower Halva Stability and Texture by Controlling Tahini Particle Size Distribution

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ABSTRACT

Sunflower halva is an appreciated product, but shows currently a quality below the expectations of the new generation of consumers, having a hard texture and oil exuded on the surface (low stability). The aim of this work was to assess the influence of tahini particle size on sunflower halva texture and stability. Eight different particle size sunflower tahini samples were produced at pilot plant scale, the higher the number of passes through the colloidal mill, the smaller the particle size (P1- coarsest → P8 - finest). Halva prototypes (25g / piece), including also an industrial sample (H0), were obtained at laboratory scale by mixing the nougat with tahini. The texture was evaluated on Stable micro systems TA.HD Plus texture analyzer equipped either with a cylinder probe or with a blade set. All samples were stored for 60 days at 4°C, room temperature (~25°C) or 40°C. During storage, the colloidal stability of all samples was assessed by a gravimetric technique. Tahini samples P6 → P8 were not suitable for halva production while due to the low viscosities, the product was impossible to be shaped. Among obtained sunflower halva prototypes (H1 → H5) it was shown that decreasing tahini particle size decreased sunflower halva hardness and stability. For each sample, the increase of storage temperature decreased sunflower halva stability. Sunflower halva H3 was the most efficient, while was more stable and showed smaller hardness values than H0.

Keywords: *halva, tahini, stability, texture, sunflower.*

INTRODUCTION

Halva is a popular confectionery product characteristic to Middle East, Indian, North African and Central East European countries. Davidson (2006) noted that in 7th century, in Arabia, halva meant a “paste of dates kneaded with milk”. However, the same author also mentioned halvav Indian roots, while in the northern part of India it has given its name to the caste of confectioners – “the halvais”. Tannahill (1988) considered halva to have Arabic roots, the name “halva” coming from “hulw”, the Arabic term for “sweet”. In the

9th century, halva was more or less a stiff paste prepared from toasted or fried semolina or wheat flour mixed gently at heat together with a sweetening agent such as sugar syrup, date syrup, grape syrup, or honey, flavorings being added such as nuts, rosewater, or pureed cooked carrots (Mureșan *et al.*, 2013). According to Davidson (2006) the halva best known in Europe and North America is a non-grain type, sesame halva. However, in Eastern European countries sunflower halva became characteristic due to the appreciated taste of sunflower seeds as well as

their great availability in this region (Racolta *et al.*, 2010; Mureşan *et al.*, 2010). This type of halva consists of a mixture of sunflower tahini (milled roasted sunflower kernels) and nougat (boiled sugar and glucose syrup beat with soapwort root extract).

Usually processed foods are multicomponent heterogeneous systems that are far from thermodynamic equilibrium (Mezzenga, 2007). However, they can be kinetically stable over a large period of time, which determines their shelf life (Schramm, 2005). During food products storage time, many chemical, physical, and biological reactions occur serially and simultaneously. As perceived by consumers, some of these changes may lead to the development of desirable attributes, such as aromas in aged wines and cheeses, but others create flavors, colors, or textures that impact negatively on quality. So, the shelf life can be defined as the length of time for which a product can be stored before the appearance of the first characteristic that consumers find unappealing, e.g., oil separated on surface, rancidity, texture that is too tough (Loveday *et al.*, 2009).

Even if sunflower halva is an appreciated product, shows currently a quality below the expectations of the new generation of consumers, having a hard texture and oil exuded on the surface (low stability). Oil separated on the halva surface is considered a usual phenomenon since years, occurring naturally right after the production and being obvious after less than one week of storage. It has been accepted as it is, and was always associated as a normal characteristic attribute of this type of products. However, considering the new consumers trends aiming high quality and elaborated products, this issue becomes detrimental causing low product marketability and lack in demand of new consumers' generation.

Damir and Abdel-Nabey (1990) emphasized the importance of oil separation from tahini and halva, considering it a serious defect, due to the troubles caused in handling and storage, and the loss entailed. They showed firstly, that sunflower halva was less stable than sesame halva and secondly, the addition of 1% glycerol monostearate had a satisfactory effect in stabilizing tahini and halva type products. The oil separated from sunflower halva containing 1% glycerol monostearate after 90 days storage at room temperature was 3.1%.

Studies have been conducted on similar products colloidal stability, such as sunflower tahini (Damir, 1984), sunflower butter (Lima and Guraya, 2005; MacDonald, 1985), sesame halva (Ereifej *et al.*, 2005; Gunesser and Zorba, 2014) sesame tahini (Çiftçi *et al.*, 2008) or peanut butter (Aryana *et al.*, 2003; Francisco *et al.*, 2006; Gills and Resurreccion, 2000; Totlani and Chinnan, 2007). Oil separation and oxidative stability of these confectionery products is a current research topic while also Ahmad *et al.* (2013) reviewed the quality of nut spreads which are products similar to sunflower tahini, emphasizing the same issues.

Recently, our group Mureşan *et al.* (2013) had reviewed sunflower halva production technology and its quality alterations, stressing the importance of research on this product. A facile available solution was rapidly tried (Mureşan *et al.*, 2014a), by the addition of a saturated fat, which allowed the development of a network structure and immobilizing the free oil. The optimum sample in terms of stability and texture contained 3% palm oil, the study revealing encouraging results. However, the study did not allowed the understanding of sunflower halva instability phenomenon. It has to be mentioned that sunflower tahini is the single ingredient added on halva which contains fat, so it contributes essentially to sunflower halva instability. Thus, starting by understanding the physico-chemical properties and structure of sunflower tahini, our group (Muresan *et al.*, 2014b) studied the rheology of different particle size tahini prototypes. It was shown the importance of particle size on tahini behavior and structure, while starting from the same raw material, with the same chemical composition, but utilizing different milling strategies in order to prepare different particle size tahini, led to prototypes with very different rheological properties (e.g., prototypes that were high viscous and high thixotropic, with high volume fraction to light viscous and slightly thixotropic with low volume fraction, industrial reference being intermediate). In another paper published by our team (Mureşan *et al.*, 2015), we studied the influence of particle size distribution and storage conditions on sunflower tahini colloidal and oxidative stability, in order to find solutions to oil separation and rancidity issues encountered on sunflower halva production process. It was shown that colloidal and oxidative stability of sunflower tahini

decreased, as the storage time and temperature increased. For the particle sizes range studied, and including a commercial available sunflower tahini, the coarsest sample was the most stable tahini in terms of oil separation. However, concerning oxidative stability, coarsest tahini sample was less stable as commercial tahini, being even at initial time more oxidized due to milling technology used.

Thus, in order to continue the work done on sunflower tahini stability (Mureşan *et al.*, 2015), and to evaluate also halva final product behavior, the aim of this paper was to assess the influence of tahini particle size and storage conditions on sunflower halva texture and stability.

MATERIALS AND METHODS

Obtaining of sunflower tahini samples

According to previously published paper (Muresan *et al.*, 2014b), eight different particle size sunflower tahini samples were produced at pilot plant scale, the higher the number of passes through the colloidal mill Microcut MCV 12B (Stephan Machinery GmbH, Hameln, Germany), the smaller the particle size (P1- coarsest → P8 - finest).

Obtaining of sunflower halva samples

The nougat was obtained by classical technology (Racolța, 2008) from boiled sugar and glucose syrup beat on the presence of soapwort extract (*Saponaria officinalis* L.). Halva samples (25g / piece) corresponding to different particle size sunflower tahini, including also a commercial halva sample (H0), were obtained at laboratory scale by mixing the nougat (40%) with tahini (60%). Sample H0 was manufactured from sunflower tahini obtained industrially in a two steps process – a three-roll refiner and a beating machine (Racolța, 2008). In order to obtain efficiently different halva samples, the kneading as well as molding was performed at laboratory scale. Particle size distributions as well as rheological properties of the nine samples were presented and discussed by Muresan *et al.* (2014b).

Texture analysis

The texture was evaluated on a Stable micro systems TA. HD Plus Texture Analyzer (Stable Micro Systems, Godalming, Surrey, UK) equipped either with a cylinder probe (P/0.5, $\Phi\frac{1}{2}$ ", Derlin) or a HDP/BSW blade set. The analysis were performed at a room temperature of 25°C, the test

speed being set at 0.5 mm/s, Pre-test speed at 0.5 mm/s, Post-test speed at 2 mm/s.

Storage test and oil separation quantification

All samples were stored for 60 days at $4\pm 1^\circ\text{C}$, room temperature ($25\pm 3^\circ\text{C}$) or $40\pm 1^\circ\text{C}$. During storage, the colloidal stability of all samples was assessed by a gravimetric technique, with a precise determination of the percentages of the exudate oil. Each sunflower halva sample was weight (w_{sample}) and wrapped on perforated aluminum foil, being placed with the perforated side down, into a suitable container padded with absorbent paper in advance. For spacing the sample from absorbent paper, three rods were placed in-between perforated aluminum foil and absorbent paper. The oil separated from the product leaked through perforations and was absorbed by the paper. At different periods during the 60 days of storage, the weight of separated oil ($w_{\text{sep.oil}}$) was obtained by difference between current and initial weight of padded container. The result was expressed in % by mass, of separated oil from the sample, computed with equation:

$$\% \text{ separated oil} = w_{\text{sep.oil}} / w_{\text{sample}} \cdot 100 \quad (1)$$

Statistical methods

In order to show the effect of particle size distribution, storage time and temperature on the colloidal sunflower tahini stability, three-way ANOVA General Linear Model, as well as one-way ANOVA and Tukey's comparison statistical tests were used.

RESULTS AND DISCUSSIONS

Sunflower halva samples

Tahini samples P6 → P8 were not suitable for halva production while due to the low viscosities encountered, the product was impossible to be shaped. Thus, for all further analysis were taken sunflower halva samples H1 → H5 (H1 – coarsest; H5 – finest) obtained from correspondent P1 → P5 sunflower tahini samples, together with the commercial reference H0.

Texture analysis

Testing the texture of sunflower halva highlights quality improvement opportunities by studying the mechanical and physical properties of the final product as affected by process type and parameters or by alternative ingredients.

Moreover, on halva manufacturing chain, monitoring final product texture will assure a constant quality, attribute desired and expected by nowadays consumers. Through many texture parameters, hardness [kg] is one of the main important characteristic being defined as the maximum load required to compress a sample. It is calculated as the peak load obtained when compressing a product. The texture curves recorded on sunflower halva samples obtained on this work are presented in Figure 1 (penetration test – cylinder probe), and Figure 2 (Shear blade test), the hardness values being marked on each correspondent curve.

For both texture tests performed, sunflower halva sample H1, obtained from the coarsest particle size tahini P1, recorded the highest values of hardness, 26.95 kg and 24.89 kg, respectively. The obtained hardness values clearly showed that a halva obtained from a very coarse tahini is not suitable for consumption. Thus, the high value of sample H1 hardness could be explained by tahini P1 superficial milling (one pass through the mill), which determined a very high viscosity (Power law consistency coefficient K of 3049 Pa•sⁿ) and a high volume fraction ($\Phi=0.69$), as measured by Muresan *et al.* (2014b). Due to the coarse milling, few oil was released as continuous phase of tahini P1 suspension, hence the final product, halva sample H1 showed very high values of hardness. In terms of particle size distribution this sample confirmed its coarse appearance with cumulative volume percentages of 9.61%, 43.03% and 47.36% for small particles SP (~0.2 to ~2µm), middle class particles MP (~2 to ~60µm), and large particles LP (> ~60µm), respectively (Muresan *et al.*, 2014b). On the other hand, for the softness halva obtained on this work, sample H5, due to load values lower than trigger force, the texture curves could not be registered for both texture tests performed. It has to be mentioned that samples H4 and H5, even if could be molded, presented difficulties on maintaining properly the shape, characteristics confirmed also by the small hardness values of sample H4. All samples were produced from the same batch of roasted sunflower kernel with the same chemical composition (total fat 60.07%; crude protein 20.55%; ash 3.87%; moisture 0.73%) but with different milling degrees (1 to 8 passes through the mill). The higher milling degrees (as reported also by Muntean *et al.* (2013)

for wheat) caused more cell breakages of roasted sunflower cotyledons, and consequently, with particle size diminution, more oil was released as continuous medium of the suspension, causing troubles on shaping due to low viscosities. There is paucity on literature related on sunflower halva texture, in order to compare the obtained results. However, for a similar product, xixona turrón (typical Spanish confectionery product made from toasted almonds, sugar, inverted sugar and honey), Vázquez-Araújo *et al.* (2006) recorded hardness between 1.09 and 2.23 kg when measuring with a 5mm wide cylindrical probe, values which are in agreement with current study fine sunflower halvas.

When using the shear blade assembly, hardness values for most of the samples were slightly lowers, explained by the probe geometry characteristics that facilitate a more easily samples compression by cutting. However, the ranking was

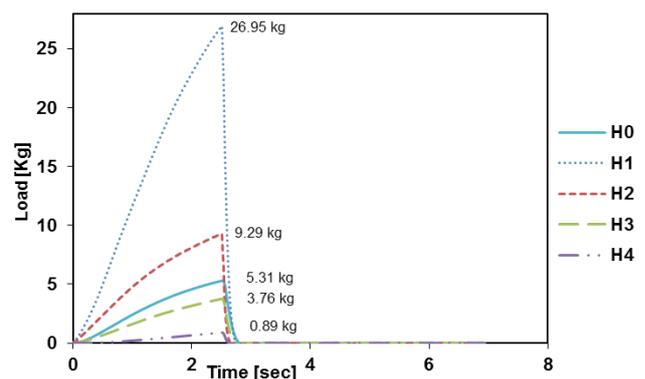


Fig. 1. Compression test performed at 0.5 mm/s using a cylinder probe (P/0.5, $\Phi\frac{1}{2}$, Derlin) on sunflower halva samples: H1 – coarsest \square H4 – finest, H0 – commercial reference.

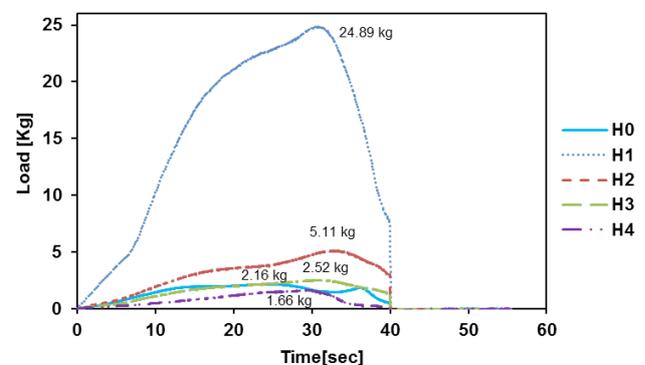


Fig. 2. Shear blade test performed at 0.5 mm/s using a Warner-Bratzler Blade HDP / BSW probe on sunflower halva samples: H1 – coarsest \square H4 – finest, H0 – commercial reference.

similar with penetration test, H1 showing the highest value of hardness and H4 the lowest.

Thus, it should be stated that even when starting from same roasted kernel, the milling process degree and consequently the particle size, affected sunflower halva texture: the smaller the particle size the lower the values of sunflower halva texture curves. In terms of consumers' preference, the desired sunflower halva is the one obtained from fine particles tahini with a soft texture and a permanent shape, but also with no exuded oil on the surface. Sample H3 seems to best match texture and shape sunflower halva characteristics.

The effect of tahini particle size and halva storage time and temperature on its separated oil levels

ANOVA General Linear Model was performed in order to assess the influence of tahini particle size and halva storage time and temperature on its separated oil levels. The three factors were *tahini particle size* with six levels: P0 – commercial and P1 – coarsest → P5 – finest; *storage temperature* with three levels: 4°C, room temperature (RT) and 40°C and *storage time* with six levels: 3, 10, 21, 35, 49 and 60 days.

The Analysis of variance for separated oil levels had demonstrated high significant differences ($p < 0.0001$) for tahini particle size and halva storage time and temperature main effects as well as for their first and second order interactions (Table 1). The statistical R^2 , which is appropriate to compare models, explains 99.38% of data variability.

Measures of effect size in ANOVA are measures of the degree of association between an effect (e.g., main effect, an interaction) and the dependent variable. It can be interpreted as the proportion

of variance in the dependent variable that is attributable to each effect (Becker, 2000). Levine and Hullett (2002) mentioned that eta squared (η^2) is the most commonly reported estimate of effect sized for the ANOVA, the term “effect size” being used in a general sense, including what also might be labeled variance accounted for, magnitude of effect, and strength of association. Pierce *et al.* (2004) defined classical eta-squared as the proportion of total variation attributable to a factor / interaction, and it ranges in value from 0 to 1. Classical eta-squared is computed as follows:

$$\text{classical } \eta^2 = \frac{SS_{\text{factor}}}{SS_{\text{total}}} \quad (2)$$

where, SS_{factor} is the variation attributable to the factor and SS_{total} is the total variation. In a recent study Richardson (2011) suggested that classical η^2 can be used to compare the effects of different between subjects or within subjects' factors in the same design.

Concerning the experiment from this study, it was considered appropriate to calculate the proportion of the total variability attributable to each factor / interaction. This proportion is described by eta squared and is manually calculated in Table 1 for each factor / interaction using Equation 2. The relative effect sizes (eta squared) on the separated oil values of sunflower halva for the studied factors (sample particle size, storage temperature, storage time) and their first and second order interactions are presented in Figure 3.

This pie chart is used to graphically display proportion of total variance that is attributable to each effect. The entire circle represents the total sum of squares. Each slice of the pie is an effect

Tab. 1. Three-way analysis of variance for sunflower halva separated oil levels

| Source of variation | SS | MS | F-value | P-value | Eta squared (η^2) |
|-------------------------|----------|---------|---------|---------|--------------------------|
| Sample particle size | 1598.028 | 319.606 | 3868.58 | *** | 0.56 |
| Temperature | 277.807 | 138.904 | 1681.32 | *** | 0.10 |
| Time | 435.923 | 87.185 | 1055.3 | *** | 0.15 |
| Sample*Temperature | 207.666 | 20.767 | 251.36 | *** | 0.07 |
| Sample*Time | 76.223 | 3.049 | 36.9 | *** | 0.03 |
| Temperature*Time | 207.016 | 20.702 | 250.58 | *** | 0.07 |
| Sample*Temperature*Time | 38.821 | 0.776 | 9.4 | *** | 0.01 |
| Error | 17.845 | 0.083 | | | 0.01 |
| Total | 2859.329 | | | | |

*** high significant ($p < 0.001$); SS – Sum of Squares; MS – Mean Squares; F-value = Fisher's statistic.

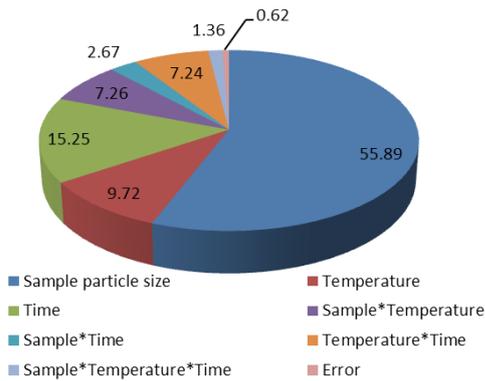


Fig. 3. Relative eta squared effect sizes (eta squared) on the separated oil levels from sunflower halva for the studied factors and their interactions.

/ interaction or the SS for error. The percent of the pie represented by each slice is the effect size, η^2 . The main effects Tahini particle size, Storage time, and Storage temperature accounted 55.89%, 15.25%, and 9.72%, respectively of the variability in separated oil levels of sunflower halva, evidencing thus the importance of Tahini particle size > Storage time > Storage temperature (considering the order) on sunflower halva stability. Among interactions Tahini particle size * Storage temperature and Storage temperature * Storage time had the highest importance accounting 7.26% and 7.24%, respectively of the variability in sunflower halva separated oil levels while the others interactions gathered together less than 5% of variability. The sum of squares for error represents 0.62 %.

Oil separation levels of sunflower halva samples during storage under different conditions

The levels of oil separated from different particle size sunflower halva samples, during storage at 4°C, room temperature and 40°C are presented on Figure 4 A–C and statistically analyzed on Table 2. When interpreting a factorial ANOVA, it is always wise to first interpret higher-order terms before lower-order terms. If statistically significant, they tell more than do lower-order terms (Denis, 2011). As the three-way interaction Sample*Temperature*Time (Table 1) is statistically significant ($p < 0.001$), implies that that separated oil levels of sunflower halva depend upon the combination of sample particle size, storage time, and storage temperature. If an interaction is significant, any lower order

interactions and main effects involving terms of the significant interaction are not considered meaningful (Minitab help file, 2011). Thus, the three-way interaction Sample*Temperature*Time is discussed in detail. Several one-way ANOVA were performed in order to: *compare samples* for each storage time and temperature (Table 2, identically first capital letters indicate no significant differences, $p > 0.05$); *compare storage times* for each sample and storage temperature (Table 2, identically lowercase letters indicate no significant differences, $p > 0.05$); *compare storage temperatures* for each sample and storage

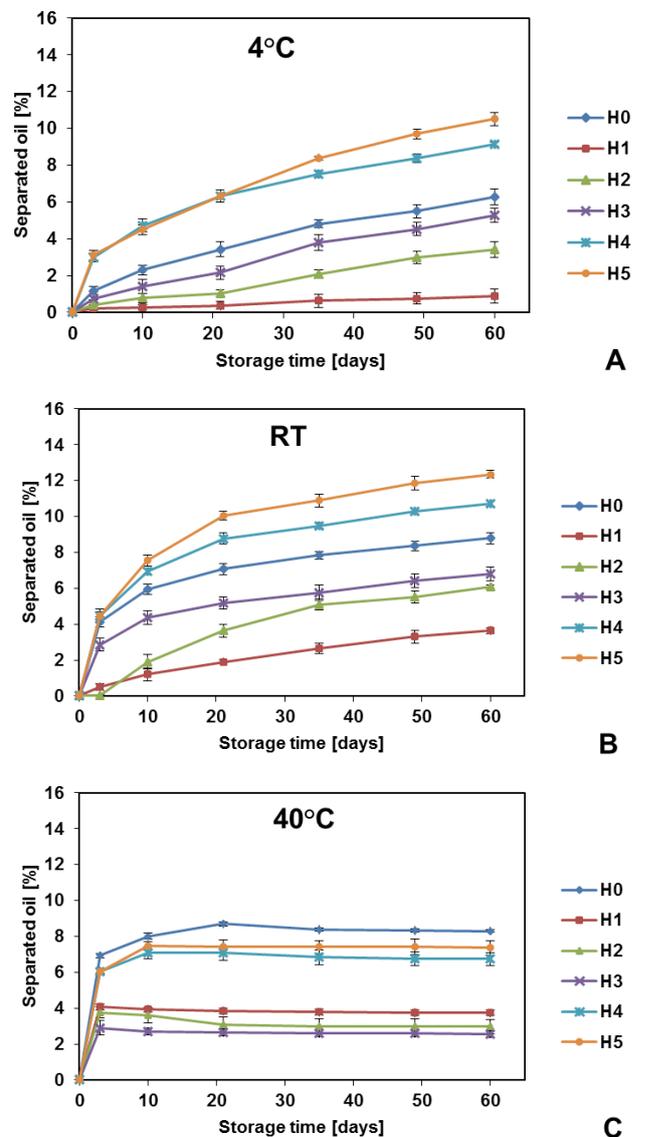


Fig. 4. Sunflower halva oil separation during storage at 4°C (A), room temperature RT (B) and 40°C (C); samples: H1 – coarsest → H5 – finest, H0 – commercial reference.

time (last capital letters indicate no significant differences, $p > 0.05$).

As demonstrated through this work, for room temperature and 4°C, the separated oil differed significantly between samples, when measured between 30 and 60 days of storage. Sample H5 separated the most of the oil and H1 the fewest, samples ranking being H5>H4>H0>H3>H2>H1. At 40°C, H3, H2 and H1 separated the fewest oil and H0, H4 and H5 the most. With little exceptions, in each group, the separated oil levels did not differ significantly between samples.

Concerning storage time comparison, for all samples at room temperature and 4°C it was a clear statistically significant increasing of the separated oil with the increasing of the storage time. However, for each sample at 40°C, there was no statistically significant difference between the separated oil after 10 days of storage. This fact might be explained by the sharp increase of the

separated oil in the first days, this exuded oil being prone to oxidation at higher temperature, causing lipid polymerization, hence increasing the viscosity of the separated oil at the product surface and interrupting the oil exudation from the product. The oxidation processes were corroborated also by the slightly decrease of the separated oil due to the decomposition of primary oxidation products into smaller volatile compounds (e.g., aldehydes, ketones) and/or polymerized compounds (form dimmers or oligomers).

Regarding the comparison between studied storage temperatures, for each sample there was a higher oil separation from sunflower halva stored at 40°C in first three storage days, after this period due to the facts discussed above (i.e., lipid oxidation) the oil separation being stopped. There was a clear decreasing of separated oil at 4°C as compared to room temperature, no matter what sample or storage time.

Tab. 2. Statistics of separated oil [%] (means \pm standard deviations) of sunflower halva stored for three months at 4°C, room temperature and 40°C

| Sample | Storage temperature | Storage Time | | | | | |
|--------|---------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| | | T1 3 days | T2 10 days | T3 21 days | T4 35 days | T5 49 days | T6 60 days |
| | | Separated oil [%] | | | | | |
| H0 | 4°C | 1.18 ^{BcC} \pm 0.20 | 2.29 ^{BdC} \pm 0.25 | 3.43 ^{BcC} \pm 0.40 | 4.80 ^{CbC} \pm 0.21 | 5.49 ^{CabB} \pm 0.37 | 6.28 ^{CaB} \pm 0.44 |
| | RT ¹ | 4.13 ^{AeB} \pm 0.30 | 5.93 ^{BbbB} \pm 0.30 | 7.07 ^{CcB} \pm 0.31 | 7.83 ^{CbcB} \pm 0.23 | 8.36 ^{CaB} \pm 0.28 | 8.79 ^{CaA} \pm 0.32 |
| | 40°C | 6.93 ^{AdA} \pm 0.11 | 8.01 ^{AcA} \pm 0.17 | 8.69 ^{AaA} \pm 0.11 | 8.38 ^{AbA} \pm 0.10 | 8.34 ^{AbA} \pm 0.09 | 8.30 ^{AbcA} \pm 0.09 |
| H1 | 4°C | 0.22 ^{CaB} \pm 0.12 | 0.26 ^{DaC} \pm 0.14 | 0.36 ^{DaC} \pm 0.22 | 0.62 ^{FaC} \pm 0.36 | 0.75 ^{FaB} \pm 0.31 | 0.90 ^{FaB} \pm 0.38 |
| | RT | 0.50 ^{CdB} \pm 0.19 | 1.20 ^{DcdB} \pm 0.37 | 1.90 ^{FcB} \pm 0.13 | 2.65 ^{EbB} \pm 0.29 | 3.29 ^{FabA} \pm 0.35 | 3.64 ^{FaA} \pm 0.16 |
| | 40°C | 4.06 ^{CaA} \pm 0.17 | 3.93 ^{CaA} \pm 0.12 | 3.84 ^{CaA} \pm 0.16 | 3.78 ^{CaA} \pm 0.17 | 3.75 ^{CaA} \pm 0.16 | 3.73 ^{CaA} \pm 0.15 |
| H2 | 4°C | 0.40 ^{CcB} \pm 0.28 | 0.76 ^{CdC} \pm 0.27 | 1.04 ^{DcB} \pm 0.20 | 2.07 ^{EbC} \pm 0.24 | 2.97 ^{EaB} \pm 0.32 | 3.43 ^{EaB} \pm 0.42 |
| | RT | 0.04 ^{CeB} \pm 0.04 | 1.89 ^{DdB} \pm 0.40 | 3.63 ^{EcA} \pm 0.34 | 5.11 ^{Dba} \pm 0.33 | 5.50 ^{EabA} \pm 0.34 | 6.06 ^{EaA} \pm 0.13 |
| | 40°C | 3.77 ^{CaA} \pm 0.30 | 3.58 ^{CaA} \pm 0.39 | 3.08 ^{CdaA} \pm 0.44 | 2.98 ^{CdaB} \pm 0.42 | 2.99 ^{CDaB} \pm 0.41 | 2.96 ^{CDaB} \pm 0.41 |
| H3 | 4°C | 0.75 ^{BcB} \pm 0.33 | 1.41 ^{CeC} \pm 0.17 | 2.15 ^{CdB} \pm 0.06 | 3.78 ^{DcB} \pm 0.30 | 4.53 ^{DbB} \pm 0.27 | 5.29 ^{DaB} \pm 0.13 |
| | RT | 2.85 ^{BeA} \pm 0.36 | 4.36 ^{CdA} \pm 0.37 | 5.17 ^{DcdA} \pm 0.35 | 5.74 ^{DbcA} \pm 0.43 | 6.43 ^{DabA} \pm 0.38 | 6.78 ^{DaA} \pm 0.38 |
| | 40°C | 2.91 ^{DaA} \pm 0.41 | 2.72 ^{DaB} \pm 0.19 | 2.65 ^{DaB} \pm 0.19 | 2.58 ^{DaC} \pm 0.19 | 2.59 ^{DaC} \pm 0.18 | 2.57 ^{DaC} \pm 0.18 |
| H4 | 4°C | 2.98 ^{AfC} \pm 0.25 | 4.72 ^{AeB} \pm 0.36 | 6.31 ^{AdB} \pm 0.33 | 7.51 ^{BcB} \pm 0.19 | 8.36 ^{BbbB} \pm 0.25 | 9.13 ^{BaB} \pm 0.11 |
| | RT | 4.47 ^{AeB} \pm 0.39 | 6.93 ^{AdA} \pm 0.16 | 8.77 ^{BcA} \pm 0.31 | 9.49 ^{BbA} \pm 0.16 | 10.30 ^{BaA} \pm 0.14 | 10.72 ^{BaA} \pm 0.13 |
| | 40°C | 6.05 ^{BbA} \pm 0.12 | 7.07 ^{BaA} \pm 0.33 | 7.08 ^{BaB} \pm 0.41 | 6.84 ^{BabB} \pm 0.40 | 6.76 ^{BabC} \pm 0.38 | 6.73 ^{BaC} \pm 0.38 |
| H5 | 4°C | 3.12 ^{AfC} \pm 0.26 | 4.49 ^{AeB} \pm 0.25 | 6.32 ^{AdC} \pm 0.32 | 8.39 ^{AcB} \pm 0.11 | 9.69 ^{AbB} \pm 0.25 | 10.50 ^{AaB} \pm 0.37 |
| | RT | 4.46 ^{AeB} \pm 0.25 | 7.54 ^{AdA} \pm 0.29 | 10.05 ^{AcA} \pm 0.23 | 10.89 ^{AbA} \pm 0.37 | 11.87 ^{AaA} \pm 0.36 | 12.36 ^{AaA} \pm 0.20 |
| | 40°C | 6.06 ^{BbA} \pm 0.15 | 7.46 ^{ABaA} \pm 0.24 | 7.42 ^{BaB} \pm 0.40 | 7.42 ^{BaC} \pm 0.35 | 7.41 ^{BaC} \pm 0.42 | 7.36 ^{BaC} \pm 0.42 |

¹ Room Temperature; T1 \rightarrow T6 – storage times; For each storage temperature and time, identically first capital letters indicate no significant differences ($p > 0.05$) between studied samples; For each sample and each storage temperature, identically lowercase letters indicate no significant differences ($p > 0.05$) between storage times; For each sample and each storage time, identically last capital letters indicate no significant differences ($p > 0.05$) between storage temperatures.

CONCLUSION

Tahini samples P6 → P8 were not suitable for halva production while due to the low viscosities, the product was impossible to be shaped. Among obtained sunflower halva prototypes (H1 → H5) it was shown that decreasing tahini particle size decreased sunflower halva hardness and stability. For each sample, the increase of storage temperature decreased sunflower halva stability. Sunflower halva H3 was the most efficient, while was more stable and showed slightly smaller hardness values than H0.

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