Optimization of oil retention in sesame based halva using emulsifiers and fibers: an industrial assay

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Abstract Oil bleeding during storage oleaginous seeds based confectionery products is a major problem affecting acceptance by consumers. Halva is a popular sweet food prepared from a sesame paste and a sugar mixture. The objective of this work was to improve the oil retention in this product by incorporating commercial fibers and emulsifiers: soya lecithin and monoglycerides (MG1 or MG2) during manufacturing. Oil retention yield was optimized on small batches, by response surface methodology using a central composite design applied with two factors, emulsifier concentration (0.25–2.25 %) and fibers concentration (0–2 %) at three levels. A centrifugation test was optimized to assess oil retention in halva samples. The experimental response (oil retention) was fitted with quadratic equations for each emulsifier, using multiple regression analysis. The emulsion stability increased with increasing the emulsifier concentration, particularly to 2.25 %. The oil bleeding assessed at 45 °C was slow but yielded similar results to those estimated by centrifugation test. The latter seems an attractive rapid method to quantify oil retention in oleaginous seeds and crops based food matrices. At an industrial scale, the increase of MG1 concentration to 2.25 % in halva enhances the oil retention of the product but does not affect its color or textural characteristics. Microscopic observations allowed us to explain high oil retention in this

product by a homogeneous dispersion of oil droplets in the aqueous phase.

Keywords Halva · Oil retention · Centrifugation · Emulsifier · Monoglycerides · Response surface methodology · Industrial scale production

Abbreviations

CCD	Central composite design
Df	Degree of freedom
MGs	Monoglycerides
MG1	Monoglyceride 1
MG2	Monoglyceride 2
OR	Oil retention yield
RSM	Response surface methodology
SL	Soya lecithin
SS	Sum of square
X ₁ and X ₂	Independent variables
Y	The response

Introduction

Many confectionary products, such as baklava and halva are made out of oleaginous seeds and crops paste (Gamli and Hayoglu 2012; Özer et al. 2012; Zygoura et al. 2007). A major problem affecting stability of these products during storage is oil release that reduces their marketability. Sweetened sesame paste, known as halva, halaweh or halvah, is a popular sweet food widely consumed in northern Africa, southern Europe and Middle East (Sezgin and Artik 2010; Ereifej et al. 2005; Guneser and Zorba 2014; Var et al. 2007). It's prepared by mixing sesame paste (Tahina, Tahini, Tahin), obtained by grinding dehulled and roasted

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sesame seeds, with sugar syrup, citric acid, and *Saponaria officinalis* root extract. Flavoring agent (almond or pistachio nuts, chocolate, dehydrated fruits, ...) can be added to improve nutritional value and satisfy consumer preferences. This product has a high lipids (32 % w/w), carbohydrates (47 % w/w) and proteins (13 % w/w) contents (Zygoura et al. 2007).

During storage, a quantity of sesame oil migrates from the food matrix to the surface and contaminates the packaging. This emulsion instability causes the toughness of halva and reduces marketability (Ereifej et al. 2005). In the literature, there are many studies on chemical and microbiological properties of halva (Sezgin and Artik 2010; Sengun et al. 2005; Var et al. 2007). However, the studies on oil separation problem in halva are very limited. Recent researches show that some food additives, such as sorbitane derivatives, fibers and emulsifiers can improve emulsion stability in halva (Elleuch et al. 2014; Ereifej et al. 2005; Gunesser and Zorba 2014). Emulsifiers are surface active agents that are widely used in oil-rich food preparations to promote the formation and stabilization of the emulsion (Orthoefer 2008). In 2006, the world market for food emulsifiers was estimated to be around 400 000 t, approximately 10 % of which is monoolein. Of the 40 emulsifier production units across the world, 25 are located in the United States (Pagliaro and Rossi 2010). Mono- and diglycerides are the most widely used emulsifiers in the food industry. They can be produced by chemical hydrolysis of triacylglycerols (Arcos and Otero 1996; Barrault et al. 2002; Hwang et al. 2009). Monoglycerides (MGs), which contain two free hydroxyl groups, exhibit stronger surface activity than diglycerides (Hasenhuettl 2008). Sawa et al. (2009) showed that adding monopalmitin, monostearin or monoolein softens the crumb of bread. Likewise, it was shown that adding monostearin in the formulation of low-fat yogurt, improves rheological quality of the product and limits the phenomenon of syneresis (Aguirre-Mandujano et al. 2009). In cookies, MGs increase firmness and allowed to reduce the proportion of dietary fat in the product (Goldstein and Seetharaman 2011). MGs are often used in confectionery to improve the smoothness and the “mouthfeel” of low fat content products (Weyland and Hartel 2008). Lecithins, which are mixture of phospholipids composed mainly of phosphatidylcholine, are also used as food emulsifiers (Oke et al. 2010). Commercial sources of lecithins include oleaginous seeds such as soybeans, rapeseeds and sunflower seeds and animal sources such as egg yolk, milk and brain tissue.

Most of researches on the halva oil exudation issue were limited to the laboratory scale (Elleuch et al. 2014; Ereifej et al. 2005; Gunesser and Zorba 2014). In this paper, we aimed at reducing the oil exudation in halva prepared at an industrial scale by using various concentrations

of commercial emulsifiers (lecithins and monoglycerides) to stabilize the emulsion and fibers known for their capacity to increase oil holding in food preparations (Elleuch et al. 2008; Sangnark and Noomhorm 2003). The response surface methodology was used to optimize the oil retention (response). The results of this study will be a useful scientific source for confectionary manufacturers to tackle the oil separation phenomenon occurring during storage.

Materials and methods

Raw materials

Halva products were formulated using sesame paste and nougat (sugar mixture) obtained from local processors (Confiserie TRIKI-Moulin, Sfax, Tunisia). Emulsifiers provided by TRIKI-Moulin confectionery (Sfax, Tunisia) are soya lecithin (SL) and two distilled monoglycerides MG1 and MG2 produced from hydrogenated palm oil. Both monoglycerides contain mainly long chain saturated fatty acids 58.06 % C_{16:0} and 40.68 % C_{18:0} for MG1 and 65.34 % C_{16:0} and 33.49 % C_{18:0} for MG2. Commercial fibers derived from corn were also provided by the confectionery.

Halva samples preparation

Sesame paste and nougat used to prepare halva were made at an industrial scale in Confiserie TRIKI-Le Moulin factory (Sfax, Tunisia) (Fig. 1). Small batches of Halva were prepared by mixing sesame paste, nougat, *Saponaria officinalis* root extract, emulsifier and fibers in a stainless steel blender (KRUPS, France) equipped with a kneading hook for 1 min 50 s at the lowest speed. The conditions were optimized by sensory evaluation. The samples were then filled into alimentary plastic containers. The different formulations are illustrated in Table 1.

Optimization of the centrifugation method

The control of oil exudation in halva during storage under ambient conditions requires some weeks. The centrifugation is the common method to accelerate the destabilization of emulsions and simulate the oil separation of the product (Latreille and Paquin 1990). The parameters of the centrifugation (speed and time) are adjusted according to the nature of the emulsion.

Halva was filled into small molds (to get pieces of the same size). The samples were then coated with a perforated foil. The whole is surrounded by a filter paper, which will absorb the exuded oil. The foil prevents the dough from sticking to the

Fig. 1 Diagram of halva production in the confectionery TRIKI-Le Moulin (Sfax, Tunisia)

filter paper. Cubes obtained are subjected to centrifugation at 2500×g for 10 min at 25 °C.

Oil retention yield (OR) was calculated as follows:

$$\text{OR}(\%) = \frac{[(\text{TO} - \text{EO}) / \text{TO}] \times 100}{(1)} \quad (1)$$

TO Total oil contained in the halva before centrifugation, determined by the soxhlet method based on extraction with hexane (Abaza et al. 2002).

EO Exuded oil from the halva after centrifugation as determined by weighing the sample after and before centrifugation.

Response surface methodology (RSM)

Oil retention was optimized on small halva batches by RSM using central composite design (CCD) applied with two factors (X_1 : emulsifier concentration (%), X_2 : fibers concentration (%)) at three levels (Table 2). The range and center point values of independent variables were based on literature data and economic reasons. The experimental design used for this study is shown in Table 2.

The oil retention of the three formulations of halva using commercial emulsifiers and fibers was fitted using a second-order polynomial equation and a multiple regression of the data was carried out to obtain an empirical

Table 1 The central composite design and experimental oil retention yields (Y)

Run	X_1 : Emulsifier concentration (%)	X_2 : fiber concentration (%)	$Y_{MG1}(\%)$	$Y_{SL}(\%)$	$Y_{MG2}(\%)$
1	0.25	0.0	73.74	76.98	74.57
2	2.25	0.0	84.95	75.90	83.28
3	0.25	2.0	76.77	73.35	76.31
4	2.25	2.0	84.36	73.95	83.63
5	0.25	1.0	73.04	73.74	72.55
6	2.25	1.0	84.88	77.50	82.93
7	1.25	0.0	76.77	73.35	78.89
8	1.25	2.0	78.16	75.62	77.36
9	1.25	1.0	77.36	75.10	78.06
10	1.25	1.0	78.09	75.10	77.36
11	1.25	1.0	77.71	76.11	77.36
12	1.25	1.0	75.93	74.96	78.44
13	1.25	1.0	78.58	73.42	76.45
14	1.25	1.0	76.70	73.21	77.29

MG1 and MG2 are monoglycerides and SL is soya lecithin

model related to the factors. The general form of the second-order polynomial is:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2 \quad (2)$$

Y is the predicted response, X_i are coded independent variables (X_1 for emulsifiers and X_2 for fibers), b_0 is the intercept, b_i, b_{ii} et b_{ij} are the coefficients of linear, quadratic and interactive terms, respectively. Coefficients are determined by the least squares method. The principle of the method is to choose the coefficients that make the minimum sum of squared deviations ($\sum_{i=1}^n (y_i - \hat{y}_i)^2$) between the experimental values (y_i) and those calculated ($\hat{y}_i$) by the mathematical model applied (polynomial second degree in our case). Experimental data were analyzed using NemrodW program (LPRAI, France) to estimate the coefficients, evaluate the quality of the model fitting and to deduce the optimal conditions.

Statistical analysis

The statistical significance of the regression model was checked by Fischer's test (F-test) and by the analysis of variance (ANOVA) for the response surface quadratic model shown in Table 3. The total sum of squared deviations from the mean (SS) evaluated with 13° of freedom (df) is divided into two sums of squares. The first estimated with 5 df, is due to regression (factors) that includes the effects of factors and

interactions between these factors. The second, estimated with 8 df is attributed to the residual variation that includes the lack of fit, reflecting the systematic difference between the real model and the model chosen, and pure experimental error. The quality of the model fit is considered good if the variance (SS / df) due to factors is greater than the variance due to residues (Lewis et al. 1998).

Analysis of the halva prepared at an industrial scale

Samples preparation

At this step, halva containing 2.25 % of MG1 was made totally at an industrial scale at TRIKI-Moulin factory, as shown in Fig. 1. This sample was compared with standard halva, containing a lower amount of the same emulsifier MG1.

Microscopic observation

In order to visualize the microstructure of the halva, samples were spread between a slide and cover glass and observed under an optical microscope, (Axioskop 40, Zeiss, Germany) equipped with a video system. A large number of micrographs were taken in order to select the most representative ones.

Texture analysis

Texture profile analysis was performed using a texture analyzer (LLOYD instruments, England) equipped with a 1000 N load cell. Samples were compressed by an acrylic cylindrical probe (Diameter 12 mm) to 50 % of its original height (30 mm) with a speed of 30 mm/min. Two compression cycles were done. This test simulates the mechanical action of the molars. The

Table 2 Independent variables and their levels used in the response surface design

Independent variables	Symbol	Levels		
Emulsifier concentration (%)	X_1	0.25	1.25	2.25
Fiber concentration (%)	X_2	0	1	2

Table 3 Statistical analysis of the models (ANOVA)

Source of variation	Sum of squares			Degrees of freedom			Mean square			F-value			p-value			Significance		
	MG1	SL	MG2	MG1	SL	MG2	MG1	SL	MG2	MG1	SL	MG2	MG1	SL	MG2	MG1	SL	MG2
Model	178.928	6.175	125.615	5	5	5	35.786	1.235	25.122	44.941	0.511	27.629	<0.01	76.200	0.014	****a	NS ^b	***
Residual	6.370	19.322	7.274	8	8	8	0.796	2.415	0.909									
Lack of Fit	2.677	14.023	4.892	3	3	3	0.892	4.674	1.630	1.208	4.410	3.422	39.700	7.300	11.000			
Pur Residue	3.694	5.299	2.383	5	5	5	0.739	1.060	0.477									
Total	185.299	25.497	132.889	13	13	13												
R ²	0.966	0.242	0.945															

^a NS: not significant^b ***: Statistically significant at 99.9 % of confidence level

texture analyzer is connected to a computer which controls the instrument and analyses the data using the software NEXYGEN™ MT version 4.5 (AMETEK, USA). Hardness, cohesiveness, adhesiveness and elasticity were determined.

Color measurement

Color determination was executed with CIE Lab color space using a Konica Minolta colorimeter CR-5 (Japan) with an aperture of 0.8 cm diameter. The CIE color value included L*(lightness), a*(redness) and b*(yellowness).

Sensory evaluation

In order to determine whether there is a sensory difference between the halva containing 2.25 % of MG1 and the standard product containing a lower concentration of the same emulsifier, we opted for a triangle test. Eleven panelists who were familiar with the product were chosen. Three samples among which two are identical, were coded with 3-digit numbers. The tasters were asked to select the different sample. The blends have been prepared 1 day in advance and stored at room temperature.

Statistical analysis

All analytical determinations were performed in triplicate. Means and standard deviations calculation and the mean comparison were carried out with Fisher's test at $p < 0.05$ level using Microsoft Windows Excel version 2007 (Microsoft corporation, USA).

Results and discussion

Optimizing sesame oil retention in halva using response surface methodology

Oil bleeding is a major problem affecting halva stability during storage. In order to improve oil retention, commercial emulsifiers and fibers were incorporated in small batches of halva. Nougat and sesame paste were prepared at an industrial scale then mixed with an emulsifier (monoglycerides or lecithins) and fibers, used at various concentrations.

Central composite design

The oil retention capacity of the samples (response) was optimized using the surface response methodology by applying a central composite design with two factors (emulsifier and fibers amounts). The coefficients of the mathematical models reflecting the variation of the response that is the oil retention yield (OR) according to the emulsifier (X_1) and fibers (X_2)

amounts, are determined by the least squares method Eqs. (3), (4), (5). An equation was established for each emulsifier (monoglycerides MG1 and MG2 and soya lecithin (SL)).

$$\text{OR}_{(\text{MG1})} = 77.338 + 5.107X_1 + 0.638X_2 + 1.969X_1^2 + 0.474X_2^2 - 0.905X_1X_2 \quad (3)$$

$$\text{OR}_{(\text{SL})} = 74.647 + 0.547X_1 - 0.552X_2 + 0.808X_1^2 - 0.327X_2^2 + 0.420X_1X_2 \quad (4)$$

$$\text{OR}_{(\text{MG2})} = 77.367 + 4.402X_1 + 0.093X_2 + 0.753X_1^2 + 1.138X_2^2 - 0.348X_1X_2 \quad (5)$$

The statistical significance of the regression model was checked by Fischer's test (F-test) and by the analysis of variance (ANOVA) for the response surface model shown in Table 3.

The experimental Fischer's (F_{exp}) values were 44.94 and 27.63 for MG1 and MG2, respectively. They exceed the critical Fisher's value (F_{α}) ($F_{0.001}$ (5.8)=13.5) for the given confidence level (99.9 %). This means a good fit of the models

corresponding to samples containing the emulsifiers MG1 and MG2. For soya lecithin, the variance due to regression is lesser than that due to the residues ($F_{\text{exp}}=0.51 < F_{0.05}$ (5.8)=3.69). This can be explained by a poor choice of the experimental domain that does not show a significant change in the response. The model related to soya lecithin is not retained and will not be used for surface responses plotting.

Model adequacy can also be judged by the determination of the correlation coefficient R^2 (Lewis et al. 1998) which is the ratio between the variation due to the regression and the total variation.

$$R^2 = \frac{\sum (\hat{y}_i - \bar{y})^2}{\sum (y_i - \bar{y})^2} \quad (6)$$

y_i Experimented value of the response

$\hat{y}_i$ Response value calculated by the mathematical model

$\bar{y}$ The mean of the experimented values

Fig. 2 Graphical representations of the effect of emulsifier and fibers concentrations on oil retention yield. Response surface (3-D) showing the effect of emulsifier and fiber concentrations on the oil retention in the halva for MG1 (a) and MG2 (b). Contour plots showing the effect of the emulsifier concentration and fibers concentrations on the oil retention in the halva for MG1 (c) and MG2 (d)

More R_2 is close to 1 (variation due to regression is of the same order as the total one), better is the fit. This condition is checked for MG1 and MG2 (Table 3).

Graphical interpretation of the surface response models

Surface responses and contour plots were drawn using NemrodW software (version 2000. D) (Fig. 2). Increasing the emulsifier concentration from 0.25 to 2.5 % augments markedly the oil retention yield of the halva samples from 74 to 84 %. The effects of varying the emulsifier concentration on the oil retention are comparable for MG1 and MG2. This can be explained by structural similarity between both emulsifiers produced from hydrogenated palm oil. Nevertheless, varying corn fibers concentration (from 0 to 2 %) appears to affect slightly the oil retention of samples containing MG1 or MG2 (Fig. 2). These results recall those of Elleuch et al. (2008) who showed that the addition of 1 % or 2 % of date fibers or sesame testae in the emulsifier-enriched halva did not minimize the oil separation or improve the emulsion stability at 45 °C, 50 °C or 55 °C ($p>0.05$). Hughes et al. (1997) also showed that the addition of 2 % of oat fiber did not reduce the fat loss in frankfurters. Oil holding properties of dietary fibers depend also on the relative amounts of individual fiber components, especially with regards to the soluble and insoluble fractions (Elleuch et al. 2011). Turabi et al. (2008) reported that the use of fibers (different gums) improved the fat retention in the rice cakes. Indeed, the addition 1 % of guar increased significantly ($p<0.05$) the emulsion stability from 10 to 75 % in the rice cake. Yadav et al. (2007) linked the ability of different corn fibers to stabilize emulsions to their protein content and suggested that proteins may be partially or fully responsible for the emulsifying activity.

Fibers were shown to be good oil holders *in vitro* (Sangnark and Noomhorm 2003). The effect of fibers incorporation in food products on texture and oil holding is dependent on the food matrix (Femenia et al. 1997) but also on their concentration. Using high amounts of inner pea fibers (10 %) increased the fat retention in high fat ground beef from 33 to 89 % (Anderson and Berry 2001). Based on these reported findings, one can suggest that fibers effect on oil holding in halva might be seen when using higher concentrations than those tested in this study.

Assessment of oil retention in halva during storage at 45 °C

The centrifugation test might lead to an overestimation of the oil bleeding since high values are recorded (oil retention varying from 74 to 84 %). Real exudation was assessed during storage at high temperature (45 °C) in order to enhance the oil bleeding phenomenon that occurs usually very leisurely.

Furthermore, the storage temperature (45 °C) can be reached during summer time in warm countries. Samples of halva were filled into 350 g plastic containers. In each container, six identical and regularly spaced wells are made. The containers were stored at 45 °C for 30 days. Exuded oil, accumulated in the wells, was removed and weighed.

According to the results of the experimental design, incorporating commercial fibers did not have an important effect on the oil retention in the halva. For this reason, samples were prepared by adding only the emulsifier (MG1, MG2 or soya lecithin).

Figure 3 illustrates the evolution of oil retention in the halva containing MG1 (A), MG2 (B) or soya lecithin (C)

Fig. 3 Evolution of the oil retention yield (OR, %) in the halva containing MG1 (a), MG2 (b) or soya lecithin (c) during halva storage at 45 °C

(C) at various concentrations, stored at 45 °C for 30 days. Oil retention yield was measured each 5 days. Oil retention decreased by 5 % after storage during 30 days at 45 °C for samples containing soya lecithins or small amounts of monoglycerides (0.25 or 1.5 %) (Fig. 3). This decrease is however corrected when using a high monoglycerides concentration (2.25 %). These results are in good agreement with the high efficiency of monoglyceride emulsifiers (MG1 and MG2), to increase the oil holding of halva, assessed at room temperature using the centrifugation method reported in this paper. They are also in line with other works reporting the high efficiency of monoglycerides in emulsifying food preparations (Aguirre-Mandujano et al. 2009; Guneser and Zorba 2014; Turabi et al. 2008).

The efficiency of monoglycerides to stabilize the halva formula during 30 days is likely explained by their high content in saturated fatty acids that augments their melting points (80 and 79 °C for MG1 and MG2, respectively). Using high monoglycerides amounts in the halva would increase the viscosity of the oil phase and improve the oil retention (Fig. 2), as it was suggested by other authors (Elleuch et al. 2014). This hypothesis was strengthened by Ordiz et al. (2015) who investigated the effect of emulsifier and viscosity on oil separation in ready-to-use therapeutic food, based on peanut paste. Likewise, Guneser and Zorba (2014) reported that the preventive effect of saturated fatty acids sorbitan monoglycerides on oil separation problem in sesame based halva was high compared to sorbitan monooleate. Similar results were found by

Gills and Resurreccion (2000), who showed that the hydrogenated vegetable oil was greatly more efficient than palm oil to prevent oil separation in peanut butter. Indeed, samples enriched with 1.5 % of hydrogenated vegetable oil did not exhibit any oil separation during storage for 153 days at 45 °C. However, Regardless of the amount of palm oil added,

Fig. 4 The oil retention yield (OR, %) in standard (1.25 % MG1) and emulsifier-enriched halva (2.25 % of MG1) prepared at the industrial scale

Fig. 5 Optical microscopic observation of the standard halva (1.25 % MG1) (a) and the emulsifier-enriched sample (2.25 % of MG1) (b)

from 0 to 2.5 %, oil separation reached 17 % in peanut butter stored at 45 °C for 153 days.

Lecithins seem not to be effective in reducing oil bleeding of halva (Fig. 3c), as it was described previously for other food products (Zeisel 1981). Lecithins are liquid at room temperature and have a very low melting point which would explain that their incorporation failed to prevent the oil separation.

Exudation yields determined by the centrifugation test are markedly higher than those assessed by storage at 45 °C. Even at a high temperature (45 °C), the oil bleeding is a very slow phenomenon. The centrifugation test seems therefore to destabilize the emulsion and to amplify the exudation phenomenon. It is however an attractive rapid test to assess oil retention of oleaginous seeds and crops based food matrixes.

Effect of incorporating the emulsifier on the halva prepared at an industrial scale

Determination of sesame oil retention in halva

Based on its capacity to greatly improve the oil retention of halva at a small batch scale, a high amount of monoglycerides emulsifier (2.25 % of MG1) is used for a preliminary industrial assay. Oil retention was assessed by the centrifugation method. The manufactured halva sample displays an oil retention yield higher by 4 % than that of the standard product containing a lower MG1 concentration (1.25 %) and prepared under the same conditions (Fig. 4). These results obtained at an industrial scale are in line with the experimental design carried out at a laboratory scale, showing that increasing the emulsifier concentration improves the oil retention in the halva. More trials are required to check and model the correlation between the laboratory findings and the full-scale results.

Microscopic observation

In order to understand the fact that oil retention is improved by increasing the emulsifier amount, standard (1.25 % MG1) and emulsifier-enriched (2.25 % MG1) samples were observed by optical microscopy. Micrographs illustrate different microstructure arrangements (Fig. 5). The low-emulsifier content sample displays a continuous oil phase (clear region), in which are scattered large dark droplets of various shape and

Table 5 CieLab coordinates (L*,a*,b*) of standard (1.25 % MG1) and Emulsifier-enriched halva (2.25 % MG1)

	L*	a*	b*
Standard halva (1.25 % MG1)	77.52±0.10	−0.36±0.09	6.75±0.64
Emulsifier-enriched halva (2.25 % MG1)	86.62±0.35	−0.63±0.22	5.95±0.59
Statistical significance	NS ^a	NS	NS

^a NS: not significant

size representing the aqueous phase (Fig. 5a). This microstructure is in agreement with the result obtained by Ereifej et al. (2005) who described the oil in the halva as a free fluid filling in the spaces between solid particles (proteins and sugars). The large continuous oil matrix is likely to explain that oil can freely move and easily separate from the food matrix. The oil separation occurs in oil-in-water food emulsion when the oil droplets gather and form larger droplets. This step is known as the flocculation that can lead to the coalescence when all the dispersed droplets form one phase completely separated from the continuous phase (Dickinson et al. 1996). However, the structure of the emulsifier-enriched sample shows a homogenous dispersion of oil matrix (clear region) and aqueous phases (dark region) (Fig. 5b). The oil phase regions are disconnected by a complex aqueous network and cannot form a large track, which makes separation difficult. The oil and aqueous phases arrangement in the emulsifier-enriched halva explains the improvement of oil retention as compared with the standard sample. The increasing of the emulsifier amount seems to homogenize the dispersion of the oil in the halva matrix. Studying mixing step, which is the most influent on oil phase dispersion, will be interesting to improve the oil retention in halva.

Texture analysis

Improving the oil retention capacity of halva by increasing the emulsifier concentration must not affect the textural properties of the product. Emulsifier-enriched halva was subjected to textural analysis as compared to the standard product (Table 4). No statistically significant differences ($p>0.05$) in the textural properties were noticed between of the two

Table 4 Textural properties of standard (1.25 % MG1) and emulsifier-enriched halva (2.25 % MG1)

	Hardness (N)	Cohesiveness	Elasticity (mm)	Chewiness (Nmm)	Adhesiveness (N)
Standard halva (1.25 % MG1)	117.23±2.10	0.04±0.01	11.80±2.60	56.95±3.49	4.91±0.79
Emulsifier-enriched halva (2.25 % MG1)	102.04±5.75	0.05±0.00	7.88±0.50	36.06±0.87	4.59±0.40
Statistical significance	NS ^a	NS	NS	* ^b	NS

^a NS: not significant

^b *: Statistically significant at 95 % of confidence level

samples, with regards to their hardness, cohesiveness, elasticity and adhesion. The only exception was the chewiness which was lower for the emulsifier-enriched halva ($p < 0.05$). This sample requires less effort than the standard product to be chewed into a state of swallowing. This is in line with the fact that monoglycerides incorporation was described to increase the smoothness of food products (Weyland and Hartel 2008). It is likely be due to a more homogenate microstructure of the emulsifier-enriched sample observed by optical microscopy (Fig. 5b).

Color measurement

The color is an important criterion in the acceptance of halva by consumers. CieLab coordinates (L^* , a^* , b^*) of the halva samples are measured (Table 5). There are no significant ($p > 0.05$) differences in color indices between halva samples containing 1.25 % or 2.25 % of emulsifier. Increasing the emulsifier amount in the formulation of halva increased the oil retention but did not affect the product color.

Sensory evaluation

The triangle test was conducted on halva samples evaluated by eleven panelists. Over eleven responses, five were correct which is insufficient to conclude that there is a perceptible significant difference between standard and emulsifier-enriched samples (Didier 1995). These results are in agreement with textural and color analysis. The detection of a significant difference in the chewiness by instrumental analysis (paragraph 3.2.3) is attributable to the specificity and sensitivity of the instrument which is always higher than the human perception.

Conclusions

The emulsion instability remains the problem that affects mostly oleaginous seeds and crops based confectionary products like halva. The increase of the monoglycerides concentration up to 2.25 % enhances the oil retention capacity in the halva prepared at a laboratory or at an industrial scale without affecting the texture or the color of the product. Increasing the emulsifier concentration is a good solution to prevent oil bleeding during a storage at high temperature (45 °C). Improving the halva oil retention by increasing the emulsifier concentration can be explained by increasing the viscosity of the oil phase and a more homogenous dispersion of the oil droplets and water phase. Further studies are needed to better understand the effect of varying the emulsifier composition and properties on the oil stability in confectionary products like halva. It will be also interesting to evaluate the

effect of emulsifier increasing amount on halva characteristics during storage.

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