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EFFECT OF EMULSIFIERS ADDITION ON DOUGH PROPERTIES, BACKING QUALITY AND MICROSTRUCTURE OF BISCUITS

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The effect of emulsifiers, *e.g.* Monoglyceride and Flavo 1500, and their levels (from 0.1 to 0.4% and 1.0, 1.5, 2.0%, respectively) on dough properties and baking quality of biscuits was studied. The addition of Flavo 1500 at the concentrations from 1.0 to 2.0% resulted in an increase in dough water absorption. Monoglyceride-supplemented dough did not show significant differences in water absorption compared to that of the control dough. Only in the case of dough supplemented with Flavo 1500 at highest concentration (2%), an improvement in dough stability and consistency was observed. The Monoglyceride supplementation caused a significant improvement of dough stability compared to that of control samples already at 0.1% level. The weight and volume of biscuits significantly decreased with an increasing level of Flavo 1500. The biscuits containing Flavo 1500 and Monoglyceride at the levels of 1.0% and 0.4%, respectively, were characterised by the highest value of relative shape factor (SF_R). A higher level of Monoglyceride improved all baking characteristics of the biscuits. The Monoglyceride-supplemented biscuits were characterised by crunchy-like structure. Contrary, the biscuits containing Flavo 1500 had a more rigid and open structure.

INTRODUCTION

Bakery products are important ready-to-eat processed foods. Bread, sweet-dough products, biscuits, cookies, crackers and cakes are common bakery products that are consumed widely across the world. Bakery products are no longer considered fancy or luxury teatime snack, but have become essential and significant components of the dietary profile of the population [Chavan &Kadam, 1993]. However, the nutritive value of these products could be low because of the inferior nutritional composition of wheat grain *per se*. The basic ingredient of bakery snacks – wheat proteins – are characterised by low lysine, methionine, and threonine content. Due to that fact, in many developed countries, the bakery products are very often enriched with protein, fat and sugar improvers. Ready-to-eat processed foods of longer shelf life, satisfying taste, texture, and high nutritive value seem to be the most important products that can satisfy consumers. The major bio-components of wheat flour in combination with other ingredients, such as: proteins (animal and vegetable ones), lipids, sugars, emulsifiers, as well as processing conditions strongly determine biscuits' quality. Anjum *et al.* [2000b] pointed out that bread baking quality depends not only on protein quantity but also on its quality. Therefore, many extensive works have been performed on gluten protein and the reliability of crude gluten as an indicator of flour strength for baking products. Technological quality of wheat is strongly related to the storage proteins (gliadin and glutenin) and the characteristics of these proteins must be considered when attempting to explain the quality variation observed among different wheat cultivars [Anjum *et al.*, 2000a].

Starch is another important bio-component of cereal products and its gelatinisation induces major structural changes during baking. Swollen and partially solubilised starch granules were found to act commonly with wheat proteins as essential structural elements of baking products [Autio *et al.*, 1997; Błaszczak *et al.*, 2000; Fornal, 1998; Hug-Iten *et al.*, 1999]. However, Chevallier *et al.* [2000] identified the structure of short dough as suspension of solid particles in a liquid phase being an emulsion of lipids in a concentrated sugar solution. Baltsavias *et al.* [1999] showed that irrespective of composition, starch gelatinisation was slight, presumably due to the limited water content coupled with the low baking temperature. These authors concluded that biscuits comprised a glassy matrix and their properties were mainly determined by air spaces and fat globules volume, as well as the level of inhomogeneities.

The problem of wheat quality seems to be more complicated in Egypt because wheat or end-use products such, as wheat flour, are imported from several countries. Significant differentiation in genetic and environmental origin of the imported wheat grains (flour), as well as improper storage conditions affect the technological quality of flour. The availability of continuous supply of wheat flour that produces uniform and super-quality biscuits is another difficulty in the baking industry. Considering these reasons, many studies intentionally have indicated the possibility of supplementation of wheat flour components in order to increase its quality.

The effect of additives such us: lactic acid, fat and sodium chloride on dough development and bread making properties was studied by Gujral and Singh [1999]. These authors reported an improving effect of fat content (%) on

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dough development and bread volume. Manohar and Rao [1999] reported that the addition of any emulsifier (glycerol monostearate, lecithin or sodium stearoyl lactylate) lowered the elastic recovery value, indicating their contribution to the shortening effect on gluten and also resulted in a decrease in consistency and hardness and made the dough more cohesive. Biscuits with a high level of sugar were also characterised by highly cohesive structure and crisp texture. The addition of sugar to the dough formula decreased its viscosity and relaxation time. It promotes biscuits length and reduces their thickness and weight. Apart from fat that increases biscuits length and reduces dough thickness, as mentioned-above, the quantity of water can significantly affect dough rheology, as well as dough characteristics after baking [Maache-Rezzoug *et al.*, 1998a, Maache-Rezzoug *et al.*, 1998b, Chevallier *et al.*, 2000]. As for the quantity of water, Maache-Rezzoug *et al.* [1998b] have proved the reduction of thickness and weight of biscuits along with the increasing volume of water.

This investigation was undertaken to study the effect of adding different levels of Flavo 1500 and Monoglyceride on the rheological behaviour of biscuit dough, baking quality, microstructure, as well as the organoleptic properties of biscuits. The objective was to find the proper kind and optimal proportion of emulsifiers that could be used in order to improve biscuits baking quality.

MATERIALS AND METHODS

Materials. A French soft wheat flour (SWF) of 72% extraction was obtained from a flour mill, Giza, Egypt. Commercial improvers with restricted chemical composition and name such as: Flavo 1500 and Monoglyceride were obtained from N. I. Ibraihim Company, Cairo, Egypt as well as Eastman Chemical Products, Inc., Kingsport, Tennessee, USA, respectively.

Flour composition. Flour moisture content (14%), as well as protein (N × 5.7) content (9.9%) were determined with AACC standards [1983]. Whereas ash (0.48%), fibre (0.5%) and ether extract measurements (1.2%) were done according to the AOAC approved methods [1990].

Rheological properties of dough. To evaluate the rheological properties of dough constant procedures for Mixograph and Farinograph were used [Foda *et al.*, 1987]. Water absorption, dough development time, dough weakening and tolerance index were determined using Consistograph SZ-5. The flour (80 g) with Flavo 1500 or Monoglycerides at the concentration of 1.0, 1.5, 2.0% and 0.1, 0.2, 0.3, 0.4%, respectively (wt. g/100 g of flour), was mixed at the constant temperature of 30°C for 15 min. Water absorption for control sample of flour, as well as for the flour with added emulsifiers was recorded as the amount of water absorbed by the flour sample to optimise the mixing consistency and was reported as a percentage of flour weight.

Biscuit formula. The biscuit dough was prepared according to the following formula: flour 100 g, sugar 57.77 g (powdered sugar passing through 220 μm mesh), shortening 28.44 g, sodium bicarbonate 1.11 g, salt 0.93 g, dextrose solution 14.66 g (8.9 g was re-suspended in 150 mL of water), and water 7.1 g. The concentration of all the ingredients in dough was calculated per 100 g of flour. The baking procedure was performed in a laboratory oven (type: SHEL 1370 FX with 3 trays) at 205°C for 12 min, according to the methods of AACC [1983].

Evaluation of biscuit quality. The biscuit quality measurements, including product weight, volume, specific volume, diameter, thickness, were conduced according to the AACC method 10–50D [1983]. The biscuit shape factor (SF) was calculated as the quotient of the average diameter and average thickness. The relative shape factor (SF_R) (in relation to the control sample) was calculated with the use of a mathematic formula: (diameter – thickness)/ SF × 100%.

Sensory analysis. The sensory analysis of biscuits was carried out by a panel of six experienced judges assigning scores for various quality attributes such as surface appearance, shape, size of gas cells, colour, flavour, texture, and mouthfeel of a product [Hoojjat & Zabik, 1984]. The evaluation of biscuits quality was done according to the accepted scale from 1 to 10.

Statistical analysis of data. The experiment was planned according to a completely randomised design. All the results were expressed as means of three repetitions and for sensory analysis as sum of scores, mean from six repetitions as well as standard deviation (SD), using Microsoft Excel for Windows.

Scanning electron microscope (SEM) analysis. The fragments (2–4 mm) taken from upper, middle, and lower part of biscuits were examined. The samples were defatted using diethyl ether, and after drying at room temperature, they were coated with gold in a vacuum evaporator (JEOL JEE-400). SEM microphotographs were obtained in JEOL scanning electron microscope at 10 kV of accelerating voltage.

RESULTS AND DISCUSSION

The effect of flour supplementation with an increasing level of emulsifiers on the rheological properties of dough was presented in Table 1. The addition of Flavo 1500 to the dough at the level of 2% caused an increase of water absorption compared to the control sample. However, the similar trends (a slight increase in water absorption) were observed in the case of dough supplementation with the emulsifier at 1.0 and 1.5% levels. On the contrary, the use of Monoglyceride did not affect dough water absorption. Only in the case of 0.1% addition of Monoglyceride into the dough, a reduction in water absorption was observed compared to the control sample, however, the measured values were not statistically significant.

The Flavo 1500-supplemented dough, at 1.0% and 1.5% levels, was characterised by the lowest values of dough stability and dough consistency (dough weakening), whereas 2.0% supplementation resulted in an increase of the above mentioned measured values (Table 1). Contrary to the above-presented results, the addition of Monoglyceride, already at the level of 0.1%, caused significant improvement of dough stability and consistency compared to the control sample. Further supplementation of flour with higher concentrations of Monoglyceride resulted in pro-

TABLE 1. Rheological characteristics of dough with the addition of emulsifiers.

Emulsifiers	Addition (%)	Water absorption (%)	Development time (min)	Dough weakening (min)	Dough stability (min)	Tolerance index (B.U)
Control		57.30±0.05	1.2±0.05	4.0±0.15	3.4±0.10	220
Flavo 1500	1.0	57.86±0.03	1.0±0.06	3.8±0.15	3.1±0.15	220
	1.5	57.86±0.06	1.1±0.06	3.9±0.10	3.1±0.10	225
	2.0	58.66±0.05	1.3±0.06	4.3±0.10	3.6±0.10	210
Monoglyceride	0.1	57.06±0.03	1.2±0.06	4.9±0.15	4.2±0.15	210
	0.2	57.30±0.03	1.5±0.05	4.3±0.15	3.6±0.15	230
	0.3	57.30±0.05	1.4±0.05	4.1±0.10	3.5±0.10	230
	0.4	57.30±0.05	1.1±0.06	3.3±0.10	2.6±0.10	260

gressive weakening of the dough properties. The rheological properties of dough with 0.2 and 0.3% concentrations of the emulsifier were comparable with the results of the control sample. Apparently, the Monoglyceride-supplemented dough at the highest concentration (0.4%) was characterised by the lowest dough stability and weaker consistency compared to other analysed samples, as well as the control one (Table 1). It may result from the fact that Monoglyceride at higher concentrations can affect gluten development *i.e.* its reduction, which, in turn, probably resulted in limited elastic dough properties. Highly elastic dough is not desirable in biscuit-making, since it shrinks after lamination [Maache--Rezzoug *et al.*, 1998a]. As these authors suggested, it is clear that among all analysed types and levels of emulsifiers used in that work the most desired effect on dough rheology had Monoglyceride (0.4%) followed by Flavo 1500 (1.0% and 1.5%). The changes observed in dough rheological characteristics at the above-mentioned concentrations of emulsifiers resulted from fat lubrication phenomenon, which, in turn, strongly affected the behaviour of gluten and starch. The particles of fat probably surround the flour proteins and starch granules, isolate them, and prevent the formation of starch-protein network. Due to that, Maache-Rezzoug *et al.* [1998a] observed decrease in dough mix consistency along with the concentration of fat. Addition of fat to the formula probably softened the dough and affected the density of the starch-protein network. A lower volume of water absorbed by flour supplemented with Flavo 1500 and Monoglyceride (at the levels of 1.0%, 1.5% and 0.4%, respectively) could also reflect the effect of fat lubrication although the data were not as low as expected (Table 1). According to Manohar and Rao [1999] and Maache-Rezzoug *et al.* [1998a], when fat concentration is increasing at a given consistency, an increase in the quantity of the absorbed water should not be observed. These authors reported that the lubricating effect was so pronounced due to the very little water volume required to achieve the desired consistency. Mixing of dough before proper hydration of the flour constituents caused limited formation of gluten network due to the fat presence, and resulted in formation of less elastic protein matrix. Consequently, the ability of fat to disperse the constituents of the mix is due to its insolubility in water. Thus, the addition of fat to the formula, especially at higher concentrations, softened the dough and resulted in a significant decrease of its stability (Table 1). However, the incorporation of Flavo 1500 at the highest concentration (2.0%) into the flour was shown to have significant advantage on flour water absorption and also improved the dough properties compared to the control sample. That phenomenon could be related to the dextrin properties – one of the components of Flavo 1500. In the case of 2% concentration of Flavo 1500, it was likely that the amount of dextrin was able to improve the gluten proteins – water interaction, which, in turn, affected the increase in dough stability. Other components of Flavo 1500, such as: amino acids, could also affect some of the properties of flour or dough, due to the presence of hydrophilic or hydrophobic groups.

Incorporation of both types of emulsifiers into the dough formula caused an increase in the biscuits shape factor (SF), determined as a ratio of biscuits diameter to their thickness (Table 2). The biscuits supplemented with Flavo 1500 and Monoglyceride at the levels of 1.0% and 0.4%, respectively, were characterised by the highest SF values. Similar relationship was reported between the level of supplementation of both of the emulsifiers and other physical properties

TABLE 2. Baking quality of biscuits supplemented with emulsifiers (SF – shape factor, SF_R – relative shape factor).

Emulsifiers	Addition (%)	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)	Diameter (cm)	Thickness (cm)	SF (cm)	SF_R (%)
Control		28.38±0.12	47.33±0.12	1.67±0.12	7.30±0.13	1.16±0.12	6.29±0.13	–
Flavo 1500	1.0	29.78±0.12	49.70±0.13	1.67±0.15	7.52±0.15	1.03±0.13	7.30±0.12	16.05±0.13
	1.5	29.74±0.12	48.00±0.13	1.62±0.12	7.50±0.12	1.10±0.12	6.82±0.13	8.42±0.13
	2.0	29.36±0.15	46.60±0.12	1.59±0.15	7.44±0.13	1.10±0.12	6.76±0.12	7.47±0.13
Monoglyceride	0.1	28.96±0.13	50.00±0.15	1.73±0.13	7.48±0.13	1.13±0.12	6.62±0.13	5.24±0.15
	0.2	29.36±0.15	50.66±0.13	1.73±0.13	7.35±0.15	1.10±0.15	6.68±0.15	6.20±0.13
	0.3	29.30±0.10	52.00±0.12	1.77±0.12	7.49±0.12	1.10±0.12	6.81±0.13	8.26±0.12
	0.4	30.36±0.12	56.66±0.10	1.87±0.10	7.70±0.12	1.10±0.12	7.00±0.12	11.28±0.12

of the biscuits, such as: weight and volume (Table 2). The weight and volume of biscuits significantly decreased with the increasing level of Flavo 1500. Contrary, a higher level of Monoglyceride resulted in improving all of the baking properties of biscuits.

Summarising, the supplementation of dough with Monoglyceride significantly affects biscuits baking quality, contrary to Flavo 1500.

Consequently, the addition of both emulsifiers also improved all of the measured organoleptic properties of biscuits (Table 3). The best total result (58.0 points) was found for biscuits containing Flavo 1500 at 1.0% level.

The SEM analysis of biscuits with different types of emulsifiers, such as: Flavo 1500 (Figure 1) and Monoglyceride (Figure 2), as well as at different concentrations, provided important information on microstructure. The microstructure of biscuits was different for each analysed layer (upper, middle, lower). In spite of the observed differences, the microstructure of these three layers can be characterised as a composite matrix of protein aggregates and sugars with dispersed fat particles and embedded starch granules. These observations are in close relation to those obtained by Chevallier *et al.* [2000]. The microscopic studies indicated that at the lowest concentrations of Flavo 1500 (Figures 1 a, b, c) and Monoglyceride (Figures 2 a, b, c), higher damage of starch granules was observed in the biscuits centre, compared to the lower and upper layers. On the contrary, at higher concentrations of both emulsifiers (Figures 1 d, e, f and 2 d, e, f) the differences in the layer microstructure, especially between the middle and upper layer, as well as middle and lower one, seemed to be less visible. It means that a lack of sufficient amount of water in some parts of biscuits could affect changes in starch microstructure. Quick evaporation of water from the top layer was the reason for less pronounced swelling of granules that was observed. For biscuits with more open structure also the velocity of moisture migration to the surface probably played an important role. Addition of emulsifiers, especially at higher concentrations, reduced the swelling of starch due to surrounding of the granules (Figures 1f and 2f) and isolating them from moisture and temperature influence [Chevallier *et al.*, 2000]. According to Manohar and Rao [1999], the effective reduction in starch swelling and its low degree of gelatinisation during baking was dependent on the fat level in dough. The most effective swelling of starch granules observed mostly in

TABLE 3. Organoleptic properties (determined by panel score) of biscuits supplemented with emulsifiers.

Emulsifiers	Addition (%)	Panel score		
		total	mean	SD
Control		48.0	8.00	±1.26
Flavo 1500	1.0	58.0	9.60	±0.52
	1.5	53.5	8.80	±0.75
	2.0	52.5	8.75	±0.88
Monoglyceride	0.1	51.5	8.58	±1.11
	0.2	52.0	8.75	±1.04
	0.3	53.5	8.92	±0.86
	0.4	55.5	9.25	±0.69

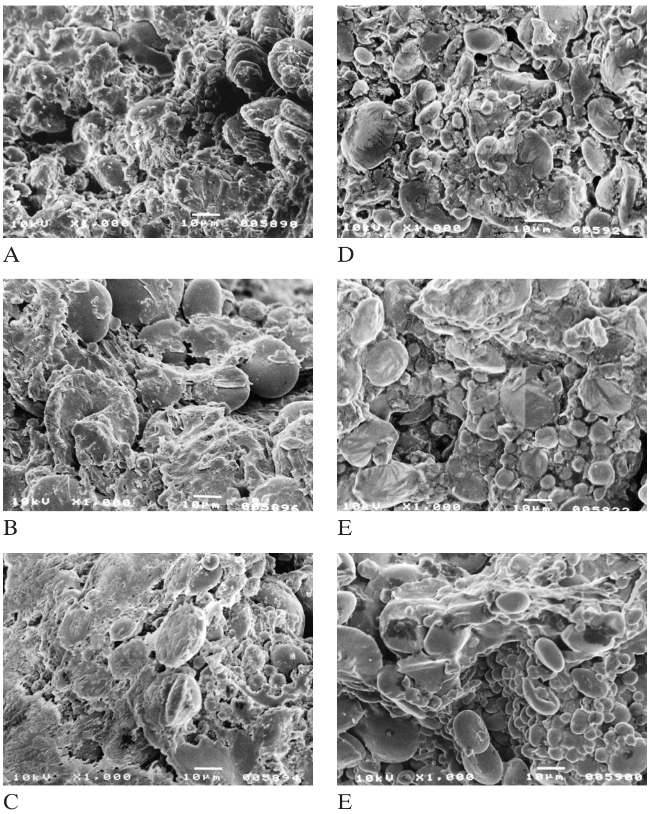

FIGURE 1. SEM photo of biscuits made with Flavo 1500; A – upper layer and 1% of addition, B – middle layer and 1% of addition, C – lower layer and 1% of addition, D – upper layer and 2% of addition, E – middle layer and 2 % of addition, F – lower layer and 2% of addition.

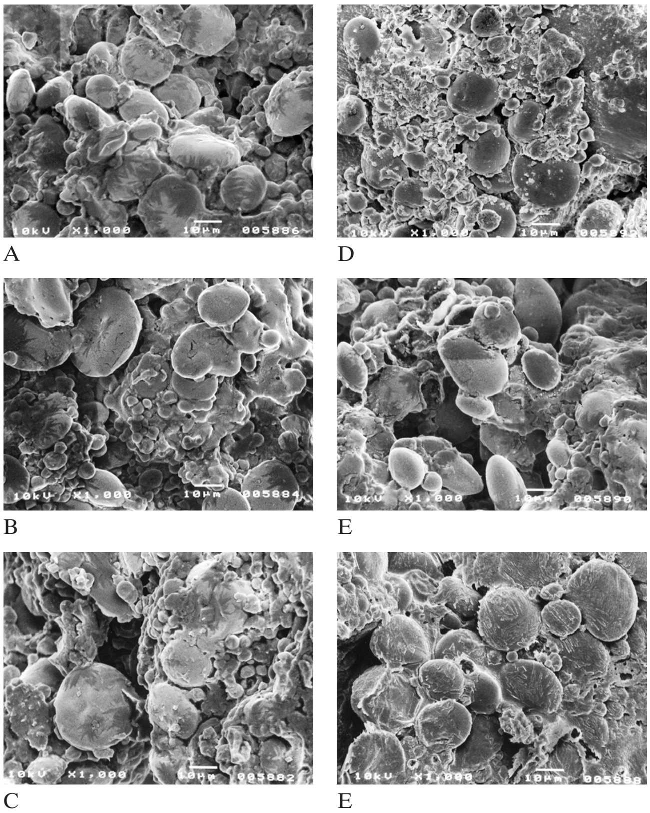

FIGURE 2. SEM photo of biscuits made with Monoglyceride; A – upper layer and 0.1% of addition, B – middle layer and 0.1% of addition, C – lower layer and 0.1% of addition, D – upper layer and 0.4% of addition, E – middle layer and 0.4% of addition, F – lower layer and 0.4% of addition.

the biscuits centre could be connected with weaker dispersion of fat particles in the middle layer. Due to that fact the swollen starch granules might probably contribute to bursting of the matrix structure, which, in turn, results in weakening of the rigid-like biscuit structure.

It was also found that differentiation between the microstructure of biscuits made with Flavo 1500 and Monoglyceride can result from the different abilities of the dough constituents to solubilise, as well as to disperse. The pictures made at low magnification (not presented) showed that biscuit made with Monoglyceride addition was characterised by weaker, crunchy-like and less ordered structure. However, the biscuits containing Flavo 1500 had more rigid, open and network-like structure. The network-like structure was always more pronounced in the lower part of biscuits and its formation seemed to be slightly dependent on the level of emulsifier.

CONCLUSIONS

It was found that Monoglyceride and Flavo 1500 influenced dough properties, baking quality and organoleptic properties of biscuits. Monoglyceride addition at 0.4% resulted in significant decrease of dough stability and consistency followed by Flavo 1500 at the levels of 1.0% and 1.5%. Improvement of dough properties was observed only in the case of 2.0% concentration of Flavo 1500 in the dough formula. The biscuits with 0.4% addition of Monoglyceride were characterised by the highest baking quality, whereas the best organoleptic properties were found for biscuits containing Flavo 1500 at the lowest (1.0%) concentration.

The biscuits made with Flavo 1500 and Monoglyceride showed significant differences in microstructure which resulted from different abilities of the dough constituents to solubilise and disperse. The Monoglyceride-supplemented biscuits were characterised by weaker and crunchy-like structure. On the contrary, the biscuits containing Flavo 1500 had more rigid and open (network-like) structure. It was found that the addition of emulsifiers, mainly at higher concentrations, resulted in the reduction of starch swelling.

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WPŁYW DODATKU EMULGATORÓW NA WŁAŚCIWOŚCI CIASTA, JAKOŚĆ I MIKROSTRUKTURĘ HERBATNIKÓW

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Badano wpływ emulgatorów (Monoglyceride i Flavo 1500) przy różnym ich dodatku (odpowiednio 0.1–0.4% i 1.0, 1.5, 2.0%) na właściwości ciasta i jakość wypiekową herbatników. Dodatek emulgatora Flavo 1500 z 1.0 do 2.0% powodował wzrost wodochłonności ciasta. Ciasto z dodatkiem Monoglyceride nie wykazało znaczących różnic w wartościach wodochłonności w porównaniu do ciasta kontrolnego. Jedynie przy największym stężeniu emulgatora Flavo 1500 (2%) obserwowano poprawę stabilności ciasta i jego konsystencji. Dodatek Monoglyceride już przy poziomie 1.0% powodował znaczącą poprawę stabilności ciasta w porównaniu do próby kontrolnej. Największą wartością względnego współczynnika kształtu SFR charakteryzowały się herbatniki z dodatkiem 1% Flavo 1500 i 0.4% Monoglyceride. Stwierdzono, że masa i objętość herbatników znacząco zmniejszała się wraz z dodatkiem emulgatora Flavo 1500. Zwiększony udział w cieście emulgatora Monoglyceride wpływał na poprawę jakości herbatników. Herbatniki z dodatkiem tego emulgatora charakteryzowały się kruchą strukturą, podczas gdy herbatniki zawierające Flavo 1500 miały bardziej zwięzłą i sztywną strukturę.