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Textural and rheological characteristics of cocoa hazelnut cream partially substituted with glucose syrup

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ABSTRACT

Texture and rheology are among the most important properties of cocoa hazelnut cream. The glucose syrup was used to substitute 2.5%, 5%, 10%, and 20% (w/w) of sugar to produce cocoa hazelnut creams. Chemical, textural and rheological analyzes in cocoa hazelnut cream samples were performed. Glucose syrups rate for accelerated oil separation and water activity was not statistically significant (P>0.05). Spreadability, stickiness, apparent viscosity, yield stress, storage and loss moduli increased with increased glucose syrups levels. Overall, glucose syrup in cocoa hazelnut cream production could be utilized to improve textural and rheological characteristics of final product.

1. Introduction

Nut spread is highly liked by consumers because of its taste, high nutritional value and can be consumed alone or with other foods. The development of nut creams will increase usage of nuts as food and introduce healthy, non-animal breakfast snacks to consumers (Shakerardekani, Karim, Ghazali, & Chin, 2013). Hazelnut creams are complex multiphase systems of different solid particulates (sugar, cocoa powder, milk whey powder, milk powder, nut, etc.) dispersed in a continuous oil phase (Glicerina, Balestra, Pinnavaia, Rosa, & Romani, 2013). The textural, color and flavor characteristics of nut creams play an important role in excite attention of consumer, purchasing decisions and final consumption (Shakerardekani et al., 2013). Particle size, suspension consistency and viscosity, which give the desired textural and sensory properties, are influenced by refining and conching (Afoakwa, Paterson, Fowler, & Vieira, 2008).

Texture, especially spreadability and hazelnut aroma are the most effective characteristics on the consumer' preference decision related to hazelnut cream (Di Monaco, Giancone, Cavella, & Masi, 2008). These type products should have good spreadability between ambient temperature and refrigerator temperature, strong creamy taste, smooth homogeneous structure without oil separation and good oxidative stability (Lončarević et al., 2016; Pajin, 2014). The final quality and properties of these products are not only due to the production process in the mixing, refining, conching and cooling stages, but also from the formulation, which has become a key parameter in the study of the rheological behavior of similar products (Fernandes, Müller, & Sandoval, 2013; Glicerina et al., 2013).

Glucose syrup is "a purified and concentrated aqueous solution of nutritive saccharides derived from starch, and having the following characteristics: (I) Dry matter of not less than 70%, (2) a dextrose equivalent (DE), expressed as d-glucose, of not less than 20% based on dry matter, (3) a sulphated ash content of not more than 1% on a dry basis". Glucose syrups can offer some functional properties in confectionery industry such as controlling sucrose crystallization and graining, reducing moisture pickup, reducing cold flow, improving processing, modifying the sweetness, modifying the texture. For chocolate spread production, the dry matter must be sufficiently high so as to prevent microbial spoilage and the viscosity must allow the end product to be easily spread and also to keep the chocolate powder in suspension. For this purpose, a syrup/sucrose mixture should be used (Hull, 2010).

It would be useful to develop a new hazelnut cream formula with glucose syrup, which has a lot of functional properties. This formulation to be obtained can help manufacturers adjust the texture of hazelnut creams. There is no study on the use of glucose syrup in nut cream samples. The aim of this study is to produce hazelnut creams with 2.5/97.5%, 5/95 %, 10/90 % and 20/80 % (w/w) glucose syrup/sucrose as sugar and to determine the effects of glucose syrup on the textural and rheological quality properties of

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cocoa hazelnut cream.

2. Materials and methods

2.1. Materials

Icing sugar (Piyale, Turkey), glucose syrup (Tito, Turkey) refined palm stearin fraction oil (Orkide, Turkey), sunflower seed oil (Orkide, Turkey), roasted hazelnut flour (Gürsoy, Turkey), cocoa (Dr. Gusto, Turkey), skimmed milk powder (Pınar, Turkey), demineralized skimmed whey powder (Maybi, Malkarabirlik, Turkey), sunflower lecithin (Tito, Turkey), salt and vanillin were purchased from local markets. Cocoa hazelnut creams were formulated with 43 g $100g^{-1}$ sugar, 20 g $100g^{-1}$ oil (95% sunflower seed oil and 5% palm stearin), 15 g $100g^{-1}$ hazelnut flour, 7 g $100g^{-1}$ cocoa powder, 10 g $100g^{-1}$ skimmed milk powder, 4.3 g $100g^{-1}$ whey powder, 0.5 g $100g^{-1}$ lecithin, 0.1 g $100g^{-1}$ salt and 0.1 g $100g^{-1}$ vanillin.

2.2. Cocoa hazelnut cream production

The glucose syrup was used to substitute 0%, 2.5%, 5%, 10%, and 20% (w/w) of sugar to produce various hazelnut creams, designated as A0, A1, A2, A3, and A4, respectively. For cocoa hazelnut cream production, ⅕ of oil to be used was placed in a melanger (two granite stones on granite bowl grinder) (ECGC–12SLTA, Cocoatown, USA). All the other dry ingredients were mixed in a bowl and these dry ingredients, ⅘ of oil and glucose syrup were gradually added into the melanger. The grinding and conching treatment was performed for 4 h in total. The final temperatures of the hazelnut creams ranged from 50 to 55 °C. Experimental samples (1 kg for each batch) were filled into 370 cc glass jars approximately 300 g and kept at 24±0.5 °C for 15 days before analyses. Two replicates of hazelnut cream production were performed; for the commercial hazelnut creams, two specimens from different lots were taken.

2.3. Accelerated oil separation

The procedure for preparing the accelerated oil separation (AOS) was adapted from Aryana, Resurreccion, Chinnan, and Beuchat (2003). Seven and a half g of sample were weighed into tube and centrifuged (10 min at 20 000 *g*). Oil separated after centrifugation was pipetted into a tube and weighed. The AOS (g $100g^{-1}$) was calculated in percentage by weight of oil that released from the 7.5 g sample.

2.4. Water activity

Water activity measurements of the hazelnut creams were carried out by using a thermostat water activity measuring device at 25 °C (AquaLab 4 TE, Pullman, WA, USA.)

2.5. Textural properties

Spreadability and stickiness analyses were performed by using TA.XT Plus Texture Analyzer (Stable Micro Systems, Godalming, UK). Hazelnut cream samples were placed in TTC spreadability rig (HDP/SR, 14580) at room temperature (24±0.5 °C). Analyze conditions were as follows; probe pre–sets distance 25 mm; test speed 10 mm s^{-1}; compression distance 23 mm. The data obtained was calculated by Texture Exponent Version 4.013.0 (Stable Micro Systems).

2.6. Rheological measurements

The rheological measurements of hazelnut cream samples were measured with a rheometer (HAAKE Mars III; Thermo Scientific, Germany) with a cone and plate system (diameter: 25 mm, cone angle: 2°, gap between cone and plate: 0.106 mm). The samples were allowed to equilibrate for 5 min at the desired temperature (25 °C), and the measurements were then conducted at this temperature. The shear rate increased linearly from 0 to 100 s^{-1} over 3 min.

The flow behavior was analyzed by using the Casson model based on the following equation (1):

$$\tau^{0.5} = (\tau_y)^{0.5} + \eta_{pl}(\dot{\gamma})^{0.5} \quad (1)$$

where τ is shear stress, τ_y is Casson yield stress, η_{pl} is plastic viscosity, $\dot{\gamma}$ is shear rate. The Herschel Bulkley model was also applied to samples (Equation (2)):

$$\tau = \tau_0 + k(\dot{\gamma})^n \quad (2)$$

where τ is the shear stress (Pa), τ_0 is the yield stress (Pa), k is the consistency coefficient ($Pa*s^n$), $\dot{\gamma}$ is the shear rate (s^{-1}) and *n* is the flow behavior index (dimensionless). Model parameters were calculated with Rheowin 4 Software v4.20 (Haake Company, Darmstadt, Germany).

Oscillatory (dynamic) tests were conducted for all samples at 25 °C from 0.1 to 100 Hz at 1 Pa (in the linear viscoelastic range (LVR) assessed by the stress sweep test). LVR of samples was determined by running stress sweep between 0.1 and 100 Pa at a constant (1 Hz) frequency. In these tests, the storage (G′) and loss (G″) modulus (Pa) were computed from raw data.

2.7. Statistical analysis

IBM SPSS software (Version 22, Chicago, USA) was used to analyze the data. The one-way ANOVA, Duncan's post-hoc test at 5% level of significance were conducted.

3. Results and Discussion

3.1. Accelerated oil separation

AOS levels in hazelnut creams were reported in Figure 1. The reason for the oil separation in such products was the differences in the specific gravity of the solid particles and the type of oil used (Gills & Resurreccion, 2000).

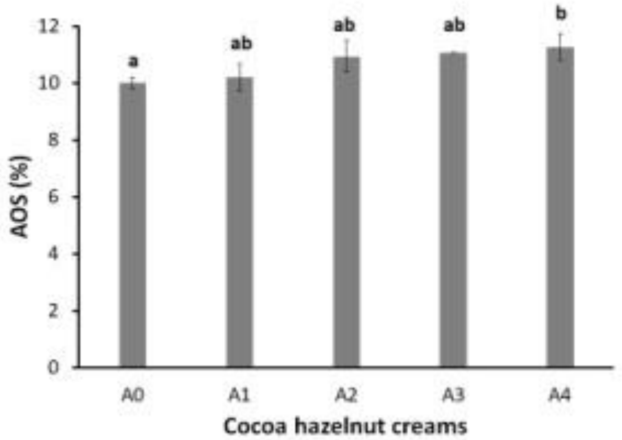

Figure 1. Accelerated oil separation in cocoa hazelnut creams.

Error bars represent the standard deviation for experiments in duplicate.

Glucose syrups rate for AOS was not statistically significant (P>0.05). While the highest AOS value was found in sample A4, sample A0 showed the lowest AOS value. It was observed that as the glucose syrup content increases, the AOS values also increase. This may be due to the different fat binding capacities of glucose and sucrose. The obtained AOS values were similar to those of Aydemir (2019a) in cocoa hazelnut cream and higher than those of Aydemir and Atalar (2019) and Aydemir (2019b) in cocoa chestnut cream.

3.2. Water activity

The water activity values ranged from 0.230 to 0.255 (Figure 2). Glucose syrups rate for water activity was not statistically significant (P>0.05). Although glucose syrup contains water, when it is replaced with sucrose up to 20%, it did not cause a change in water activity and did not disturb the general texture of the product. The obtained water activity values were similar to those of Aydemir (2019b) in cocoa chestnut cream.

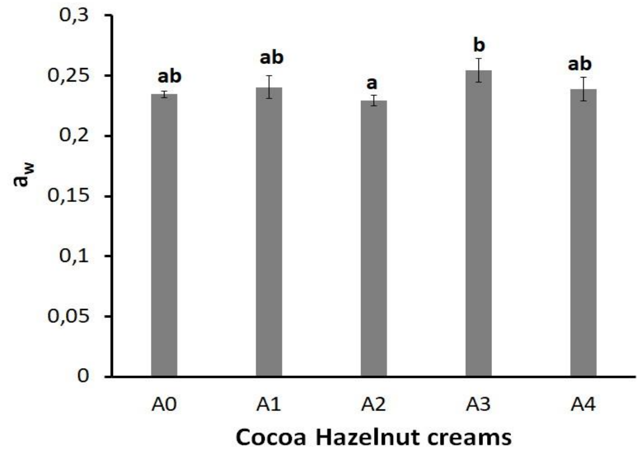

Figure 2. Water activity levels in hazelnut creams. Error bars represent the standard deviation for experiments in duplicate.

3.3. Textural characteristics

Spreadability values of hazelnut creams are shown in Figure 3. As the glucose syrup rate increases, the spreadability values also increase (P<0.05). Sample A4 was the most difficult to spread. With different glucose syrups, it is possible to modify the texture of a piece of confectionery.

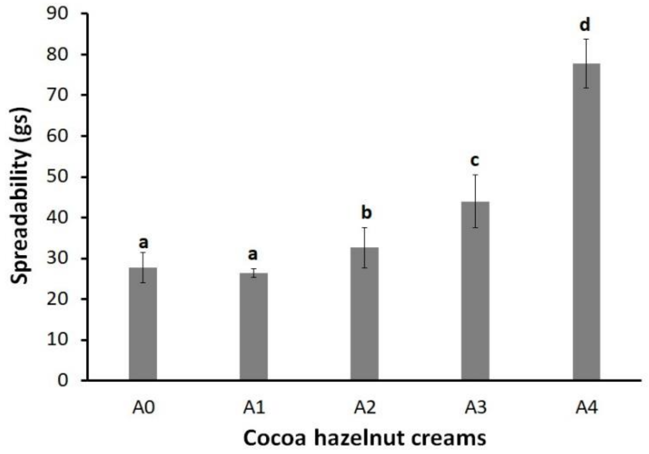

Figure 3. Spreadability values of cocoa hazelnut creams. Error bars represent the standard deviation for experiments in duplicate.

In the case of a chocolate spread, glucose syrup supplies the viscosity (Hull, 2010). The obtained spreadability values were lower than those of Aydemir (2019a) in cocoa hazelnut cream and those of Aydemir and Atalar (2019) and Aydemir (2019b) in cocoa chestnut cream.

Stickiness levels of hazelnut creams are given in Figure 4. As the glucose syrup rate increase, the samples exhibited higher stickiness values (P<0.05). A similarity was observed between stickiness and spreadability characteristics. The obtained stickiness values were lower than those of Aydemir (2019a) in cocoa hazelnut cream and those of Aydemir and Atalar (2019) and Aydemir (2019b) in cocoa chestnut cream.

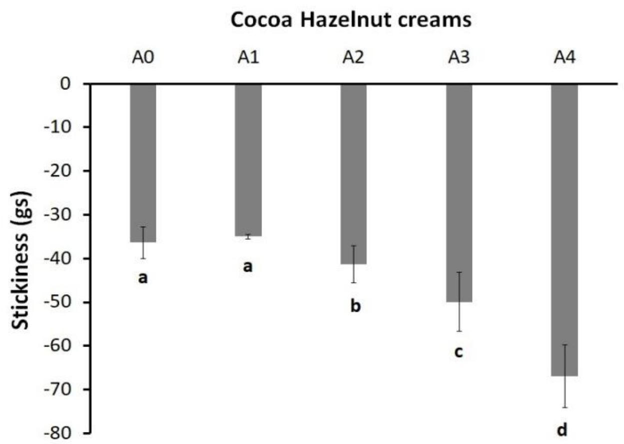

Figure 4. Stickiness values of cocoa hazelnut creams. Error bars represent the standard deviation for experiments in duplicate.

3.4. Rheological characteristics

The rheological properties of chocolate are important for manufacturing, confectionery quality assurance and accurate weight measurements. All the samples exhibited a shear thinning (a non-Newtonian fluid type) behavior (Figure 5), in which the viscosity of the samples decreased as the shear rates increased, which was in agreement with previous findings (Aydemir, 2019b; Aydemir & Atalar, 2019; Fernandes et al., 2013).

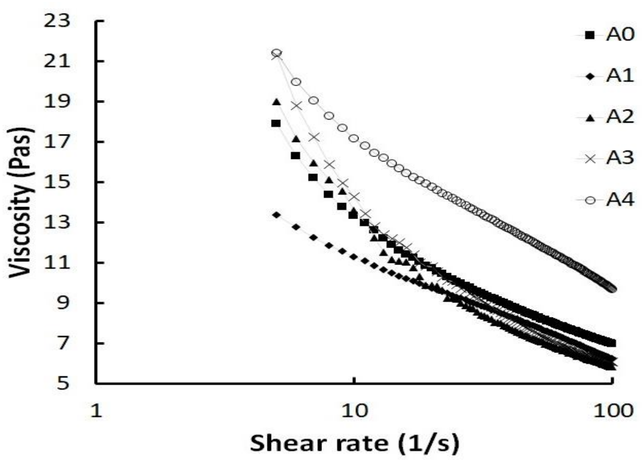

Figure 5. Apparent viscosity of hazelnut cream samples

In this study, various rheological models such as Casson, Ostwald – de Waele, Herschel–Bulkley, Bingham and other ones were applied to the samples. Casson and Herschel – Bulkley models described the flow behavior of the hazelnut cream samples successfully with the highest coefficient (R^2) values 0.9961 – 0.9991 and 0.9995 – 0.9999, respectively. The Casson model has often been successfully applied to analyze the rheological properties of chocolates (Afoakwa, Paterson, Fowler, & Vieira, 2009; Aidoo, Afoakwa, & Dewettinck, 2014). Table 1 shows yield stress (τ_y), the consistency index (k), the flow behavior index (n) and apparent viscosity at 50 s^{-1} shear rate values obtained from the Herschel-Bulkley model and τ_y, n, η_{pl} values obtained from Casson model.

The addition of glycose syrup to hazelnut cream affected their flow properties differently depending on the concentration. While increasing the glucose concentration from 2.5% to 10% did not make a significant difference (P>0.05) on the apparent viscosity values, it did result in a significant increase in the 20% glucose concentration compared to the control samples (P<0.05). This increase may be due to the high moisture content of glucose syrup (Afoakwa, Paterson, & Fowler, 2007; Aidoo, Depypere, Afoakwa, & Dewettinck, 2013). In the study carried out by Ozdemir, Dagdemir, Ozdemir, and Sagdıc (2008), where glucose syrup was used instead of sucrose in ice cream making, a higher viscosity value was found in ice cream using glucose syrup. The samples to which 2.5% glucose syrup was added exhibited significant differences (P<0.05), non-significant *k* values were found in other concentrations compared to the control sample.

Chocolate behavior is often described by two viscosity parameters known as yield stress (related to the energy to start it flowing) and the plastic viscosity (energy required to keep a non-Newtonian liquid in motion). Compared to control sample the Casson plastic viscosity value increased in the 2.5% glucose syrup added, while it decreased as the glucose syrup concentration increased. As Casson plastic viscosity is related to pumping properties, increasing the glucose syrup concentration make easier the pumping properties of the samples as it decreases the viscosity (Aidoo et al., 2014).

Yield stress parameters are derived from the steady shear flow by applying both Casson and Herschel – Bulkley model (Table 1). Increasing the glucose concentration increased the yield stress of samples (P<0.05), which indicated the formation of firmer structured systems. Correlation coefficient of 0.91 was observed between Casson yield value (τ_y) and yield stress (τ_0). High correlation coefficient between Casson yield value and yield stress was also reported by (Afoakwa et al., 2009). Spreadability has been shown to be related to rheology through a material's yield stress, the minimum shear stress required to initiate flow (τ_0) (Glibowski, Zarzycki, & Krzepkowska, 2008). This can explain the case that the sample A4 had both the value of the highest yield stress and the highest spreadability (force required to start sliding).

The storage (G′) and loss (G″) modulus as a function of frequency (Hz) are shown in Figure 6 and Figure 7, respectively. The G′ values of the samples were higher than the G″ values over the whole frequency range. This indicates an elastic structure of hazelnut cream samples rather than a viscous structure. The increase in the amount of glucose syrup was responsible for developing viscoelastic properties of hazelnut cream samples due to the water-binding properties of glucose syrup. G′ and G″ values increased as glucose syrup concentration increased.

Table 1. The parameters of Casson and Herschel – Bulkley models of hazelnut creams

Herschel – Bulkley model parameters					
Samples	τ_0	*k*	*n*	R^2	η_{app}
A0	21.66 ± 6.57^a	19.01 ± 0.19^a	0.77 ± 0.01^{bc}	0.9999	8.36 ± 0.44^b
A1	17.8 ± 6.53^a	38.4 ± 2.79^b	0.71 ± 0.01^a	0.9995	7.85 ± 0.25 ^{ab}
A2	39.18 ± 4.24^b	15.99 ± 1.88^a	0.77 ± 0.01^{bc}	0.9996	7.20 ± 0.28^a
A3	48.46 ± 1.26^b	17.51 ± 0.44^a	0.75 ± 0.01^b	0.9995	7.57 ± 0.14^a
A4	49.56 ± 0.73^b	16.31 ± 1.50^a	0.79 ± 0.03^c	0.9997	11.99 ± 0.11^c
Casson model parameters					
Samples	τ_y	η_{pl}	*n*	R^2	
A0	26.23 ± 2.48^a	4.61 ± 0.20^b	0.5 ± 0.0^a	0.9991	
A1	33.88 ± 1.35^{ab}	6.70 ± 0.03^c	0.5 ± 0.0^a	0.9961	
A2	36.29 ± 18.62^{ab}	3.38 ±0.55^a	0.5 ± 0.0^a	0.9990	
A3	43.11 ± 0.48^{ab}	3.28 ± 0.11^a	0.5 ± 0.0^a	0.9992	
A4	50.37 ± 4.64^b	4.57 ± 0.37^b	0.5 ± 0.0^a	0.9991	

τ_0: yield stress (Pa); *k*: consistency coefficient (Pa sn); *n*: flow behavior index (dimensionless); τ_y: Casson yield stress (Pa); η_{pl}: Casson plastic viscosity.
a–c The values within the same column with different letters are significantly different at P < 0.05. Values are means ± SD.

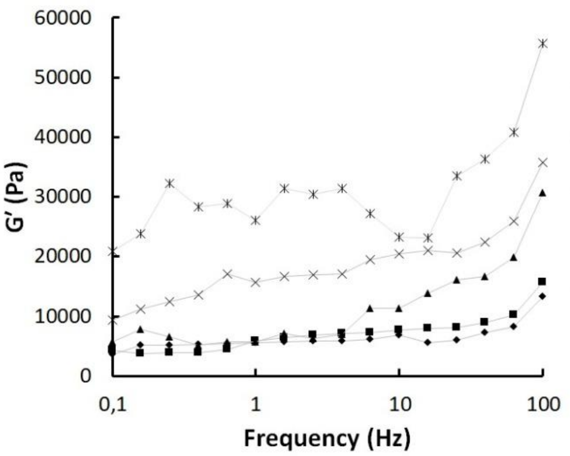

Figure 6. Plots of storage (G′) modulus as a function of frequency for hazelnut creams

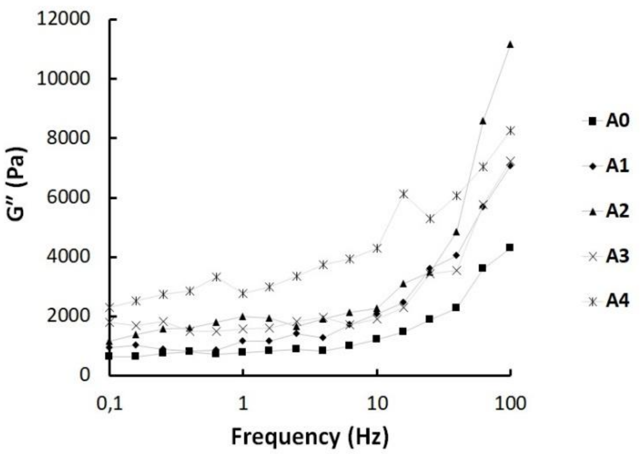

Figure 7. Plots of storage (G″) modulus as a function of frequency for hazelnut creams

4. Conclusions

A novel and successful formulation of cocoa hazelnut cream was developed. Glucose syrup could modify textural and rheological characteristics of hazelnut cream in order to meet the manufacturer's needs. The information obtained in this study showed that glucose syrups can replace 2.5-20% sugar without damaging the structure of the final product and can modify spreadability, stickiness, apparent viscosity, yield stress, storage and loss modules. Further studies may focus on different sugar syrups and their effects on theirthe chemical, textural and rheological properties during hazelnut cream storage.

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