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Effect of flour and sugar particle size on the properties of cookie dough and cookie

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Abstract: The effect of particle size of flour and sugar on the physical, sensorial and textural properties of cookie dough and cookie was investigated. According to the obtained data, both the sugar particle size and the flour particle size in cookie dough affected the hardness, adhesiveness, cohesiveness and springiness of the cookie doughs and this effect was statistically at a significant level ($P < 0.01$). The energy and force required for the dough extrusion dropped due to the reduction in the particle size of flour, while the reduction in the particle of sugar had the opposite effect. As the sugar and flour particle sizes decreased, the colour of the cookies became darker and the *L* colour values decreased. While the hardness values of the cookie samples increased with the decrease in the particle size of sugar, it decreased with the decrease in the particle size of flour. It was observed that sugar and flour particle size significantly affect cookie quality in cookie production. The formulation containing sugar and flour fractions below 150 µm has received the highest score in all sensory parameters.

Keywords: forward extrusion; fracturability; particle size; sensory properties; textural properties

Cookies are among the most popular bakery products consumed nearly by all levels of society. Some of the factors for such wide popularity are varied taste, easy availability, longer shelf life and low cost compared to other bakery products (Hrušková & Švec 2015; Jan *et al.* 2016). In addition, due to containing a high level of carbohydrates and fat, cookies are also a good source of energy (Pareyt *et al.* 2011; Yousaf *et al.* 2013; Švec *et al.* 2017).

Sucrose is the most important sugar used in the production of cookies. It is also one of the most commonly used sugars in cookie production because it does not only provide sweetness but also affects the structural and textural properties of the cookie. Moreover, it lowers the viscosity of dough as well. During baking, the undissolved sugar progressively dissolves and contributes to the spread of the cookie (Hoseney 1994; Maache-Rezzoug *et al.* 1998; Pareyt *et al.* 2009).

During wheat milling, wheat flour is obtained in different fractions depending on wheat hardness and milling technique. It is stated that the particle size of flour is very important in terms of quality flour production. Particle size of flour obtained as a result of the grinding has great importance in terms of flour quality. It has been stated that flour particle size, damaged starch and protein quantity and quality have effects on the bakery products. Because flour particle size is an important factor affecting protein quality, damaged starch content and quality of bakery products (Guttieri *et al.* 2001; Shekara *et al.* 2013; Barak *et al.* 2014).

Sensory characteristics of foods are among the most important factors affecting consumer preferences. For example, foods with a high nutritional value are not preferred by consumers if their sensory qualities are insufficient. The components used in the formulation of cookies affect the structure and tex-

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tural properties of the cookies. Most studies have investigated the effect of particle size of flour on the properties of bakery products. In a study conducted to find out the influence of flour particle size on the quality of cookie it was determined that the flour with particle size greater than 150 μm delivers better results in cookies (Barak *et al*. 2014). In another study, the effect of sugar particle size on cookie characteristics was investigated (Kissel *et al*. 1973). However, none of those studies analysed the effect of particle size of flour and sugar on the properties of cookie dough and cookie. Therefore, the purpose of this study is to research this issue.

MATERIAL AND METHODS

Flour, sugar (sucrose), shortening, sodium chloride and sodium bicarbonate used in cookie production were supplied from the local supermarkets in Erzurum, Turkey. Moisture, crude protein and total ash contents of wheat flour were determined according to AACC (1984) approved methods. The wheat flour containing 13.5% moisture, 8% protein and 0.55% ashes was used in the study. Flour and sugar particles of different sizes (> 180 μm, 150–180 μm and < 150 μm) were separated with the help of mechanical sifter using sieves of pore sizes 150 μm and 180 μm. Thus, three fractions of each of the flour and sugar were obtained.

Preparation of cookies. Cookies were prepared according to AACC approved method 10–50D (2000). The ingredients used in cookie formulation were flour (225 g), sugar (130 g), shortening (64 g), dextrose solution (33 ml), sodium bicarbonate (2.5 g), sodium chloride (2.1 g) and distilled water (16 ml). The dough was sheeted to 9 mm thickness on a dough sheeter and cut into round shape with cutter of 50 mm diameter. Baking was done in an electric oven at 200°C for 10 minutes.

Forward extrusion test. Forward extrusion test of formulated cookie doughs was performed in a TA-XT plus texture analyser (Stable Micro Systems, UK) equipped with a 30 kg load cell and operating at 5 mm/s head speed (Ronda *et al*. 2013). It measured the compression force (hardness) required for a piston disc to extrude the dough through a specific size outlet (8 mm) in the base of the sample container. The extrusion cell and the compression plunger were 2.58 and 2.55 cm in diameter, respectively. Samples were carefully scooped into cylindrical plastic containers with a spoon. The force (hardness) necessary to continue the extrusion process and the area (energy) under the curve were determined with the extrusion test. All measurements were repeated five times.

Texture analysis. Texture characteristics of cookie dough (hardness, cohesiveness, adhesiveness and springiness) were measured by TA-XT plus Texture Analyser using a 25 mm aluminium cylinder probe (Zoulias *et al*. 2000). The pieces of cookie dough formatted to 3.6 cm diameter and 9 mm thick disks was used in TPA tests and they were compressed twice down to 30% of their original thicknesses using an aluminium cylindrical probe (50 mm) at a constant speed of 1 mm/s.

Physical properties of cookies. After the cookies were baked, they were cooled for 30 min and their thicknesses and diameters were measured using digital calipers. The spread ratio which is an indicator of the quality that a cookie has obtained by the ratio of cookie diameter versus the thickness. The specific volume of the cookies was calculated by the ratio of volume to weight. After the cookies were wrapped with a plastic stretch film, the volume of the cookies was determined from the amount of water overflow when they were immersed in a cylinder filled with water. Colour was measured using a Minolta Colorimeter CR-200 (Minolta Camera Co., Japan) on the basis of L^*, a^* and b^* values (Elgün *et al*. 2002). L^* value indicates the lightness (changing from 0 dark to 100 light), a^* value gives the degree of the red-green colour (changing from –60 green to 60 red). The b^* value indicates the degree of the yellow-blue colour (changing from –60 blue to 60 yellow).

Determination of fracture properties of cookies. Cookies were evaluated measuring the peak breaking force using the 3-point break technique with the TA-XT Plus Texture Analyser (Hwang *et al*. 2016). The settings for the device were as s follows: pre-test speed 1 mm/s, test speed 3 mm/s, post-test speed 10 mm/s, distance 15 mm, trigger force 50 g. A force–time diagram was obtained for each test. The force-time plots were analysed for peak breaking force (N). The deformation of a cookie sample until it breaks during compression was recorded as fracturabillity (mm) of cookie.

Sensory evaluation. For the sensory evaluation of the cookies, a 20-person panel consisting of master and doctoral students from Ataturk University, Department of Food Engineering participated in the sensory analysis. Panelists were semi-trained and familiar with sensory analysis techniques. The cookie samples were cooled for 1 hour at room temperature after being baked

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and were evaluated in terms of colour, aroma, texture and overall acceptability by the 20-person panel using a 9-point hedonic scale. The samples were presented on white plastic plates coded with three digit numbers and served randomly (Jan *et al.* 2016).

Statistical analysis. All the experiments were carried out in triplicate and in two different trials. Statistical evaluations were performed using the SPSS package software (version 20.0; SPSS Inc., USA). The differences between the data were tested using the Duncan's multiple range tests ($P < 0.05$).

RESULTS AND DISCUSSION

The reduction in the particle size of sugar and flour significantly affected the texture profile analysis results of the cookie dough ($P < 0.01$) (Figure 1). The hardness values of the cookie dough generally increased with the decrease in sugar particle size at three different flour particle sizes (Figure 1A). The highest hardness values (6.51 N) were obtained in formulations containing flour and sugar fractions below 150 μm. The solubility of sugar used in the formulation during preparation of dough is one of the most important factors affecting hardness in cookie doughs. The hardness of cookie dough is related to the interactions between sugar and water and the development of gluten. Thus, hardness of the dough can be thought of as a function of the solubility of sugars. Dough hardness may be reduced due to the increase in the solubility of the sugar in the dough formulation. Similar results were obtained in cookies containing different sugars. Taylor *et al.* (2008) stated that sugars having greater solubility result in a more soft dough. Also, Kissell *et al.* (1973) explained that increasing the surface area of sugar reduces the solubility during dough preparation.

The adhesiveness in the cookie dough is associated with the sugar that dissolves before the baking. For this reason, the high solubility of sugar during dough formation increases its adhesiveness. When the sugar is dissolved, an increase in the total solution volume occurs within the dough. Dissolved sugar inhibits the production of gluten while creating a syrup-like environment. Therefore, more adhesive dough is formed (Curley & Hoseney 1984; Taylor *et al.* 2008). According to the data obtained (Figure 1), the reduction in sugar particle size decreased the adhesiveness values of the cookie dough. It can be said

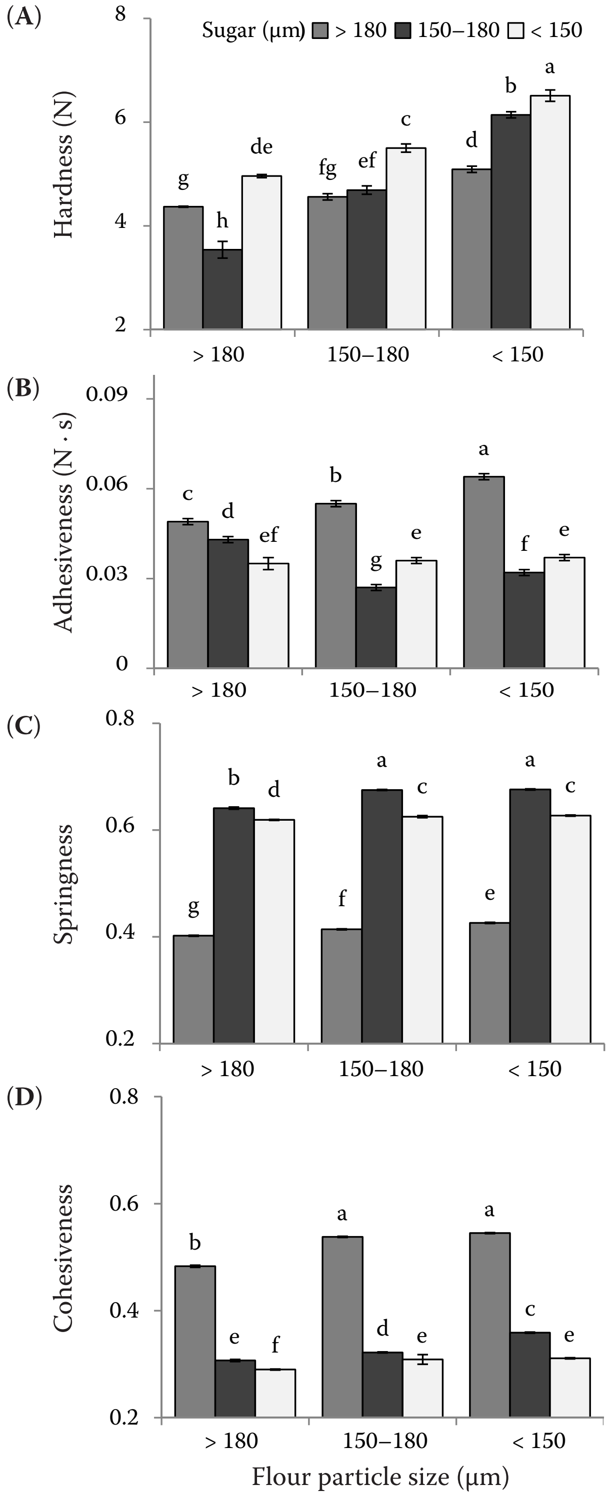

Figure 1. Effect of particle size of flour and sugar on the textural properties of cookie dough. (**A**) hardness, (**B**) adhesiveness, (**C**) springiness, and (**D**) cohesiveness

that the decrease in sugar particle size delays the dissolution of sugar during dough formation. Because Kissell *et al.* (1973) stated that during processing, sugar particles are coated with fat. As sugar particle

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size increases, less surface is available in the system, and surface area thus becomes an impressive factor in achieving dough viscosity and ultimate spread potential. Therefore, the fat layer surrounding the surface of the sugar particles may have affected the interaction between dough components.

Lower cohesiveness values indicate that the dough is crumblier or brittle. The development of the gluten network is largely responsible for the structure and cohesiveness of bakery products. However, gluten development is limited due to the high levels of sugar in cookie dough. Thus, the cohesiveness in cookie doughs does not depend only on gluten (Taylor *et al.* 2008). The cohesiveness values in the cookie dough decreased with the decrease in sugar particle size. Furthermore, the cohesiveness values of cookie dough increased with the decrease of flour particle size. According to the results obtained, it can be stated that the increase of durability of the cookie doughs is related to the decrease in flour particle size.

High flexibility is not a desirable situation when it comes to a cookie or biscuit dough. The springiness values of cookie dough increased with the decrease in sugar particle size. In other words, the flexibility of cookie dough has increased due to the increase in the sugar particle size. The lowest springiness values were obtained in the formulations containing sugar and flour fractions over 180 µm. The springiness values of cookie dough ranged from 0.402 to 0.676. The lowest springiness value (0.402) was determined in the formulation containing flour and sugar fractions over 180 µm, while the highest springiness value (0.676) was obtained in the formulation containing flour fractions below 150 µm and sugar fractions between 150–180 µm. The highest springiness values in the formulations containing flour were detected with the finer fractions. Similar observations were described by Hera *et al.* (2013) for gluten-free rice bread.

According to the results of forward extrusion (Figure 2), the energy and force required for dough extrusion increased with the decrease in sugar particle size. This increase in energy stemming from the sugar particle size may be due to delay in the dissolution of smaller particle size sugars during the preparation of the dough. On the other hand, the energy and force values of the cookie dough decreased with the decrease in the particle size of flour. The highest the energy and force values were determined in the formulation containing flour fractions over 180 µm.

Many structural, physicochemical and organoleptic changes occur during baking of bakery products

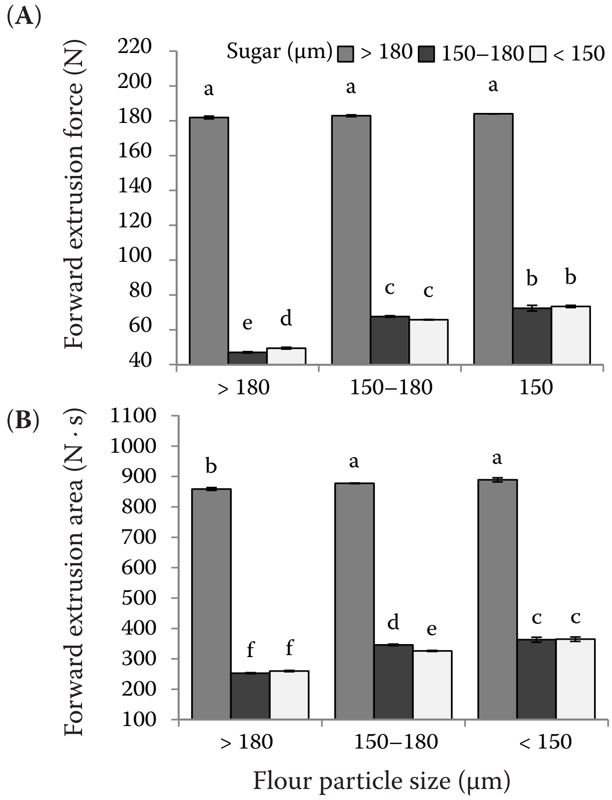

Figure 2. Effect of particle size of flour and sugar on forward extrusion parameters of cookie dough. Forward extrusion force (**A**) and area (**B**)

such as bread and cookie. All these changes during the baking are important for digestibility and sensorial acceptance by the consumers (Mohsen *et al.* 2009). The lowest scores for sensory parameters, colour, aroma, texture and general acceptability were obtained in the formulations containing flour and sugar fractions over 180 µm (Table 1). In terms of colour, aroma, texture and overall acceptability, the most favoured formulations were identified as the formulations containing flour and sugar fractions below 150 µm. These formulations received scores over 8 for all sensory parameters evaluated. A significant negative correlation between the particles size of sugar and the sensory parameters was also determined.

With the reduction in the sugar particle size, the L colour values in the cookies were significantly affected and ranged from 74.24 to 65.88 (Table 1). The $+a$ and $+b$ colour values of the samples increased with the decrease in sugar particle size. The lowest $+a$ and $+b$ colour values were determined in the formulations containing flour and sugar fractions over 180 µm. As the sugar and flour particle sizes decreased, the colour of the cookies became darker, and the L colour values decreased. The L colour

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Table 1. Effect of particle size of flour and sugar on sensory and colour properties of cookies

Particle size (µm)		Colour	Aroma	Texture	General acceptability	L	$+a$	$+b$
Flour	sugar							
> 180	> 180	5.15 ± 0.15^{c}	5.30 ± 0.30^{e}	4.80 ± 0.20^{d}	5.30 ± 0.01^{d}	74.24 ± 0.08^{a}	-1.23 ± 0.01^{g}	21.97 ± 0.46^{e}
	150–180	7.00 ± 0.01^{b}	7.15 ± 0.15^{bc}	7.15 ± 0.15^{bc}	7.15 ± 0.15^{b}	72.83 ± 0.02^{c}	2.76 ± 0.09^{e}	27.11 ± 0.03^{b}
	< 150	6.95 ± 0.35^{b}	7.15 ± 0.15^{bc}	7.45 ± 0.15^{b}	7.60 ± 0.01^{b}	71.05 ± 0.08^{e}	5.89 ± 0.09^{c}	28.05 ± 0.15^{a}
150–180	> 180	5.65 ± 0.35^{c}	5.80 ± 0.50^{de}	4.80 ± 0.20^{d}	4.80 ± 0.20^{cd}	73.59 ± 0.07^{b}	0.71 ± 0.03^{f}	23.14 ± 0.73^{d}
	150–180	6.60 ± 0.01^{b}	7.15 ± 0.15^{bc}	6.50 ± 0.50^{c}	6.80 ± 0.50^{b}	72.06 ± 0.08^{d}	3.95 ± 0.38^{d}	25.48 ± 0.20^{c}
	< 150	7.30 ± 0.30^{b}	7.80 ± 0.20^{ab}	7.45 ± 0.15^{b}	7.60 ± 0.01^{b}	68.75 ± 0.08^{f}	8.18 ± 0.06^{b}	26.97 ± 0.07^{b}
< 150	> 180	5.45 ± 0.15^{c}	5.95 ± 0.65^{cde}	5.15 ± 0.15^{d}	5.65 ± 0.35^{c}	72.85 ± 0.29^{c}	0.69 ± 0.01^{f}	22.27 ± 0.04^{d}
	150–180	6.80 ± 0.20^{b}	6.80 ± 0.50^{bcd}	6.95 ± 0.35^{bc}	6.95 ± 0.35^{b}	72.25 ± 0.09^{d}	4.54 ± 0.34^{d}	25.23 ± 0.13^{c}
	< 150	8.45 ± 0.15^{a}	8.45 ± 0.15^{a}	8.60 ± 0.01^{a}	8.45 ± 0.15^{a}	65.88 ± 0.02^{g}	9.00 ± 0.35^{a}	24.61 ± 0.05^{c}
P		*	ns	*	ns	**	*	**

Values are mean ± sd; different letters in the same column are significantly different (*P < 0.05; **P < 0.01)

values of the cookie samples generally showed a decrease due to the increase in the spread ratio. Due to the increase in spread ratio, the cookies may be more affected by the oven temperature. The results obtained in this study were similar to the study by Kissell *et al.* (1973).

The diameters of the samples were significantly affected by the decrease in the sugar particle size (P < 0.01) and the diameter of cookies increased (Figure 3). The largest diameter was found in the formulation containing sugar particle size below 150 µm. The dissolution of sugars in the formulation during baking has a high effect on the spread of cookies (Taylor *et al.* 2008). In formulations containing a smaller sugar particle size, the sugar may be dissolved during cooking and may affect the spreading ratio of cookies. Kulp *et al.* (1991) suggested that because all of the sucrose is not dissolved during the preparation of cookie dough, sugar syrup is formed during baking, leading to an increased diameter. On the other hand, the results obtained in this study for the diameter values of cookies were not similar to the study by Kissell *et al.* (1973).

Amount and type of sugar used in the cookie formulation are important factors affecting the cookie thickness (Kissel *et al.* 1973; Santiago-García *et al.* 2017). The thickness values of the cookies decreased with the decrease in the particle size of flour. Similar observations were reported by Barak *et al.* (2014) who determined an increase in the thickness values of the cookies with the decrease in particle size of flour.

Spread ratio of cookies represents a ratio of diameter to height. Thus, sugar's effects on the diameter (sugar dissolution) of cookie and height (inhibiting gluten development) of cookie are combined into a single parameter (Taylor *et al.* 2008). The spread ratio of the cookie samples increased with the decrease in particle sizes of flour and sugar (Figure 3). The highest spread ratio in the cookie samples was determined in the formulations containing sugar particle size between 150–180 µm. The decrease in particle size of sugar increased the spread ratio of the cookie samples in the formulations containing flour fractions over 180 µm, while it decreased the spread ratio in the formulations containing flour fractions between of 150–180 µm and below 150 µm. Similar observations have been described by Yamazaki *et al.* (1959) flour particle size and by Lindley (1988) for sugar particle size.

Smaller flour particle sizes would be expected to contain a higher level of damaged starch than coarse

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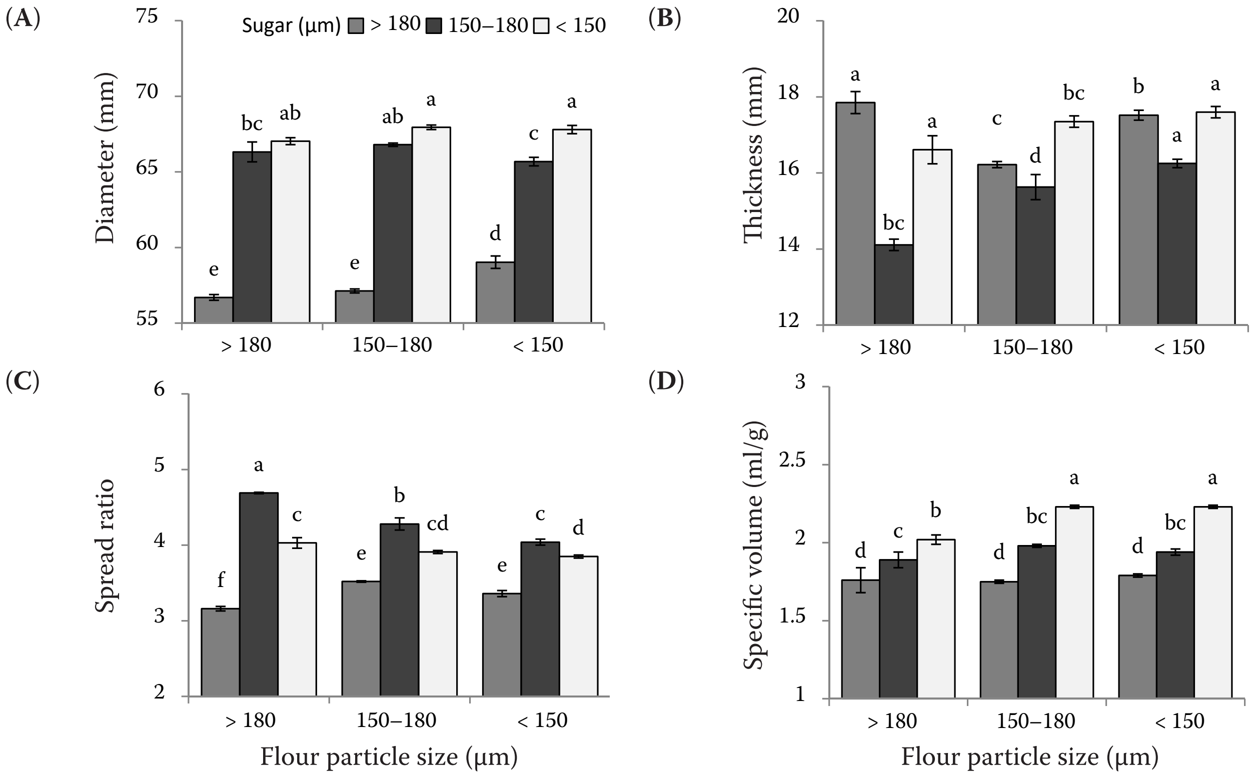

Figure 3. Effect of particle size of flour and sugar on physical properties of cookies. (**A**) diameter (**B**), thickness (**C**) spread ratio, (**D**) specific volume

flours (Zucco *et al.* 2011). Spread ratio for cookies is directly related to a particle size of flour. The reason for this is that starch is damaged during particle size reduction (Yamazaki 1959; Barak *et al.* 2014). The damaged starch content of flour affects both the spread ratio and specific volume values of the cookie. The specific volume values of the cookie samples generally increased with the decrease in sugar particle size at the three different flour fractions. The decrease in the size of the sugar particles also increased the specific volumes of the cookies, and this increase won the appreciation of the panelists.

The three-point bending test results of the studied cookies are shown in Figure 4. According to the results obtained from the breaking test, while the hardness values of the cookie samples increased with the decrease in the particle size of sugar, they decreased with the decrease in the particle size of flour. Similar observations have been described by Zucco *et al.* (2011) for pulse flour, Mcwatters *et al.* (2003) for cowpea flours and Sudha *et al.* (2007) for wheat and rice bran. Hardness values of the cookie samples ranged from 18.22 N to 26.48 N. Also, a positive correlation was determined between the hardness values and the diameter of the

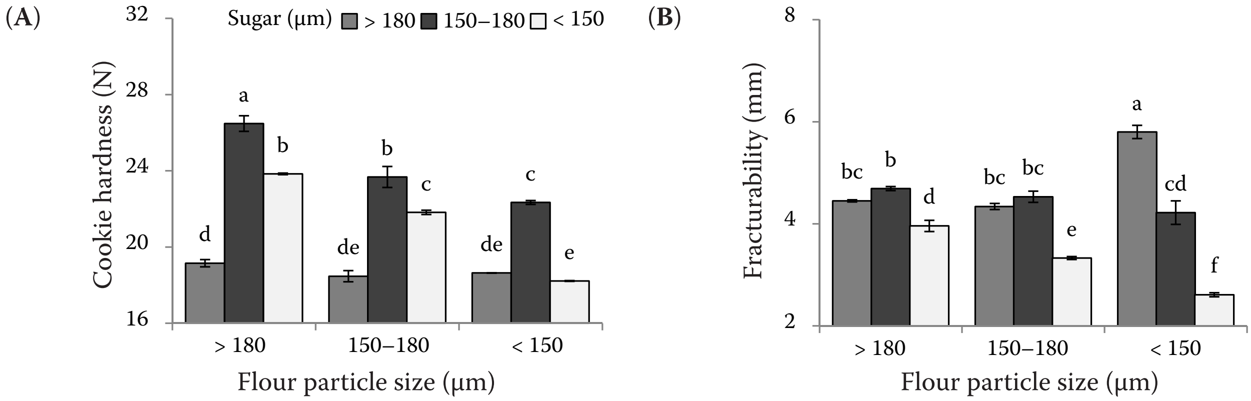

Figure 4. Effect of particle size of flour and sugar on textural properties of cookies. (**A**) hardness, (**B**) fracturability

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cookie samples. As the diameter of the cookie samples increased, the hardness values also increased.

The fracturability of cookie represents the deformation of a cookie sample until it breaks during compression. For this reason, greater fracturability values indicate higher flexibility (Hwang *et al.* 2016). The fracturability values of the cookie samples were higher in the formulations containing flour fraction below 150 µm than the other formulations. Also, it decreased with the decrease in the particle size of sugar in the formulations containing flour particle size below150 µm.

CONCLUSIONS

This study showed that the particle size of sugar and flour used in the cookie formulation significantly affects the characteristics of cookie dough and cookies. Cookie quality was positively affected with a decrease in the particle size of sugar and flour. It was observed that the effect of sugar particle size on cookie quality was more pronounced than flour particle size. Both the sugar particle size and the flour particle size in cookie dough affected the hardness, adhesiveness, cohesiveness, and springiness of the cookie doughs and this effect was statistically at a significant level ($P < 0.01$). While the energy and force values needed for the dough extrusion decreased with the decrease in sugar particle size, they also did not show any significant change with the decrease in flour particle size. As the particle sizes of flour and sugar decreased, the colour of the cookies became darker, and the *L* colour values decreased. It was observed that both flour and sugar particle size used in cookie production affects the appreciation of panelists. According to the results of the sensorial evaluation, the formulations containing sugar and flour fractions below 150 µm had the highest score from the panelists.

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