Research Article
J. Food Sci. Technol. Nepal, Vol. 13 (33-42), 2022
ISSN : 1816-0727

Effect of Shortenings and Sugar Contents on Shape and Sensory Attributes of Short-dough Biscuits

Srijana Tiwari, Salina Subedi, and Jyoti Acharya, and Anuj Niroula*

Department of Food Technology, Nagarik College, Tribhuvan University, Nepal.

*Correspondence: e-mail: an.niroula@gmail.com; tel: +977-9861779833.

Abstract

The study was aimed to evaluate the effect of shortenings (20-40 parts) and sugar (35-65 parts) contents on shape (diameter, thickness, spread ratio, and expansion ratio) and sensory attributes (color and appearance, crispness, mouthfeel, taste and flavor, and overall acceptance) of short-dough biscuits. An increase in sucrose and shortening contents significantly increased (p<0.05) diameter, and spread ratio, but significantly decreased (p<0.05) the thickness. The expansion ratio was increased with an increase in sucrose and shortening content, but a reverse effect was observed at the high contents of the other. As for the sensory attributes, each attribute was affected differently by the shortenings and sugar contents. This study revealed that the increase in shortenings and sugar contents does not necessarily increase the sensory perceptions of the biscuits. The results can be used to enhance the shape and sensory attributes of short-dough biscuits.

Keywords : Biscuit; sugar; shortening; shape attributes; sensory attributes

Introduction

Biscuits are a low moisture (<5%), energy-dense flour (usually wheat) confectionery that derives its name from the Latin word "bis coctus", meaning twice baked, as a reference to the practice of first baking the product in a hot oven and then transferring it to a cooler oven to complete drying process (Manley, 2011a; Niroula, *et al.,* 2020; Zydenbos*, et al.*, 2004). Out of several types of biscuits, short dough biscuits are the biscuits that are made from dough that lacks extensibility and elasticity (Manley, *et al.,* 2011), comparable to wet sand that holds together but crumbles easily under pressure (Zydenbos *et al.*, 2004). They are characterized by large quantities of sugar and shortening which contribute to plasticity and cohesiveness of the dough with minimal (if any) formation of gluten network referred to as "short" (Manley *et al.*, 2011; Zydenbos *et al.,* 2004).

The shape and sensory attributes of a product influence the overall consumer preference and marketability. While ingredients especially shortening and sugar are the major players, several factors like flour quality, types of sugar, mixing type, mixing time, and baking profile could influence the shape and sensory attributes of biscuits. Shortenings are a key ingredient in the preparation of short-dough as they can control the degree of gluten protein hydration by forming bonds with the protein molecules and limiting the water access to the proteins (Manley *et al.,* 2011; Zydenbos *et al.,* 2004). Shortening also softens the dough, decreases the viscosity and relaxation time further contributing to an increased length, and reduced the thickness and weight of biscuits (Maache-Rezzoug, Bouvier, Allaf, & Patras, 1998a). On the other hand, sugar controls macromolecular transformations and plays a role in the emulsive-colloidal stability resulting in the structural modification of the system (Davis, 1995; Pareyt and Delcour, 2008). Sugar also restricts the development of gluten by competing for water which otherwise would have been absorbed by the gluten that influences the shape attributes in biscuits (Maache-Rezzoug *et al.,* 1998a; Manley, 2011b; Niroula *et al.*, 2020).

The application of shortenings and sugars for the enhancement of sensory perceptions is common in baked, fried, and various other food products. In recent years, high fat and high sugar have been linked with health negative outcomes, such as dental problems, overweight/obesity, type II diabetes, and cardiovascular disease (Besnard, *et al.,* 2015; Goldfein and Slavin, 2015). Several attempts have been made for the replacement of shortenings (Jacob and Leelavathi, 2007;

Sudha*, et al.,* 2007; Zoulias *et al.,* 2002; Zoulias, *et al.,* 2000) and sugar (Handa, *et al.,* 2012; Laguna, *et al.,* 2013; Zoulias *et al.,* 2002, 2000) in biscuits. However, shortenings and sugars are multi-dimensional ingredients contributing to more than an attribute and difficult to solely replace either of them with at least a single component (Kweon *et al.,* 2009; Sudha *et al*., 2007; van der Sman and Renzetti, 2018; Zoulias *et al.,* 2002). Understanding the functionalities of these ingredients is essential for their potential replacements. Therefore, keeping all other factors constant, this work was aimed to evaluate the effect of sugar and shortening contents on shape (diameter, thickness, spread ratio, and expansion ratio) and sensory attributes (color and appearance, crispness, mouthfeel, taste, and flavor, and overall acceptance) of short-dough biscuits.

Materials and methods

Raw materials

Whole wheat flour, 92% extraction, Chakki-milled and packed by Hitesh Khadya Udyog, Nepalgunj, was used. Other ingredients used in the biscuit viz. icing sugar (Bhat-Bhateni Food Products Pvt. Ltd.), table salt (Salt Trading concern, Nepal), and baking soda (Weikfield Foods Pvt. Ltd, India) were collected from the Bhat-Bhateni supermarket of Chitwan. Shortening (PT Asianagro Agungjaya, Jakarta, Indonesia) was bought from a Shreya Bakery, Gaindakot, Nepal.

Preparation of biscuits

Biscuits were prepared with equal parts of whole wheat flour, salt, and baking soda with different proportions of shortenings and sugars as shown in Table 1. All ingredients except flour were creamed for 2 minutes, and then the flour was added to cream and mix for 3 minutes. This two-step process reduces the potential gluten formation in the dough as compared to all-in-one mixing (Manohar & Rao, 1999b). The dough was allowed to relax for about 20 minutes and then sheeted for piece formation by cutting. The dough was turned 90° after each sheeting to avoid gluten development and subsequent deformation (Laguna *et al.,* 2013). Dough sheets were maintained to 3.5 mm thickness and cut to 37 mm circular diameter. Baking was carried at 180 ± 5°C top and 200 ± 5°C bottom heat for 18±0.5 min and cooled in desiccators for 3 hours at ambient temperature. Preparation and evaluation of biscuits were carried out in 2 blocks and evaluations were 8 replicates per sample in each block.

Table 1 Recipe formulation of biscuits (weight by parts of flour)

Sample → Ingredients ↓	R1	R2	R3	R4	R5	R6	R7	R8
Flour	100	100	100	100	100	100	100	100
Icing Sugar	35	50	65	50.6	65	50	35	35
Shortening	30	30	22.9	20	40	30	40	20
Salt	1	1	1	1	1	1	1	1
Baking soda	3	3	3	3	3	3	3	3

Product evaluation

The shape (diameter, thickness, spread ratio, and expansion ratio) and sensory attributes (color and appearance, crispness, mouthfeel, taste and flavor, and overall acceptance) of short-dough biscuits were evaluated. Five biscuits were randomly chosen and stacked vertically to measure their average thickness. The biscuits were turned 90º and the average width was determined with a digital vernier caliper (Lutron, Model: DC-515). Spread ratio was calculated as the ratio of diameter to thickness of each biscuit and expansion ratio was calculated as the ratio of the final volume of biscuit to the initial volume of dough.

$$Spread\ ratio = \frac{Diameter * No.of\ biscuit\ in\ a\ stock}{Stack\ height}$$

$$Expansion\ ratio = \frac{biscuit\ volume}{dough\ volume\ before\ baking}$$

Sensory evaluation was conducted through 16 semi-trained panelists (in two blocks) using a 9-point hedonic rating (9 = like extremely, 1 = dislike) for color and appearance, crispness, mouthfeel, taste and flavor, and overall acceptance.

Statistical evaluations

The data obtained were statistically analyzed using one-way analysis of variance (ANOVA) among samples at a 5% level of significance (i.e. $p<0.05$). Tukey test was used as a post-doc test and all these analyses were performed using JMP Pro 14.

Results and discussion

The effect of shortenings (20-40 parts) and sugar (35-65 parts) contents on shape (diameter, thickness, spread ratio, and expansion ratio) and sensory attributes (color and appearance, crispness, mouthfeel, taste and flavor, and overall acceptance) of short-dough biscuits were evaluated by response surface methodology and the regression expressions for each attributes were obtained as presented in Table 2.

Shape attributes

Diameter

The diameter of biscuits was significantly affected ($p<0.05$) by shortenings and sugar contents and their interactions. The effect of shortenings and sugar contents on diameter at the low contents of each other is presented in Fig. 1a and at the high contents of each other is presented in Fig. 1b. The diameter of biscuits increased with an increase in shortenings and sugar contents. This increase could be due to the reduction in viscosity and increased mobility during the transition phase from dough to biscuit (Abboud and Hoseney, 1984; Miller and Hoseney, 1997; Pareyt and Delcour, 2008).

Table 2 Regression expressions for the effect of shortenings (20-40 parts) and sugar (35-65 parts) contents on shape and sensory attributes of short-dough biscuits

Attributes	Regression expressions
Shape	
Diameter	4.0754 + 0.0106 F + 0.0101 S – 0.0002 (F – 28.9857) (S – 47.9429)
Thickness	0.4766 – 0.0012 F – 0.0008 S – 0.00005 (F – 28.9857) (S – 47.9429) – 0.00003 (S –47.9429) 2
Spread ratio	7.5946 + 0.0652 F + 0.0553 S + 0.0016 (F – 28.9857) (S – 47.9429)
Expansion ratio	1.1352 + 0.0021 F + 0.0034 S – 0.00034 (F – 28.9857) (S – 47.9429) + 0.00033 (F – 28.9857) 2 – 0.00022 (S – 47.9429) 2
Sensory	
Color and appearance	6.2108 + 0.0586 F – 0.0029 S – 0.0041 (F – 28.9857) 2 – 0.0020 (S –47.9429) 2
Crispness	8.9564 – 0.0467 F – 0.0034 S – 0.0018 (F – 28.9857) (S – 47.9429)
Mouthfeel	4.8054 + 0.0485 F + 0.0192 S + 0.0043 (F – 28.9857) 2 – 0.0021 (S – 47.9429) 2
Taste and flavor	7.2061 + 0.032 F – 0.0118 S – 0.0011 (F – 28.9857) (S – 47.9429) – 0.0038 (S – 47.9428) 2
Overall acceptance	7.1039 + 0.0299 F – 0.0089 S – 0.0013 (F – 28.9857) (S – 47.9429) – 0.0026 (S – 47.9428) 2

Increase in diameter with increase in shortenings (Maache-Rezzoug *et al.,* 1998a; Pareyt *et al.*, 2009) and sugar (Maache-Rezzoug *et al.,* 1998a; Miller & Hoseney, 1997) contents was also reported in previous studies. Shortenings in dough reduce the apparent viscosity during baking due to the melting of fat that increases the mobility in the system (Drewnowski *et al.,* 1989; Jacob and Leelavathi, 2007). Also, with an increase in sugar contents, the volume of the total solvent in the dough is increased during baking due to the dissolution of sucrose, which reduces the viscosity of dough, increase the mobility, and leads to high lateral expansion (Handa *et al.,* 2012; Kweon *et al.,* 2009; Maache-Rezzoug *et al.*, 1998a; Miller and Hoseney, 1997; Pareyt, Talhaoui, *et al.,* 2009). It is of special note that, in all-in-one dough process and if sugar is added after creaming in two step-mixing, higher sugar contents could reduce the diameter of biscuits (Maache-Rezzoug, Bouvier, Allaf, and Patras, 1998b; Slade and Levine, 1994).

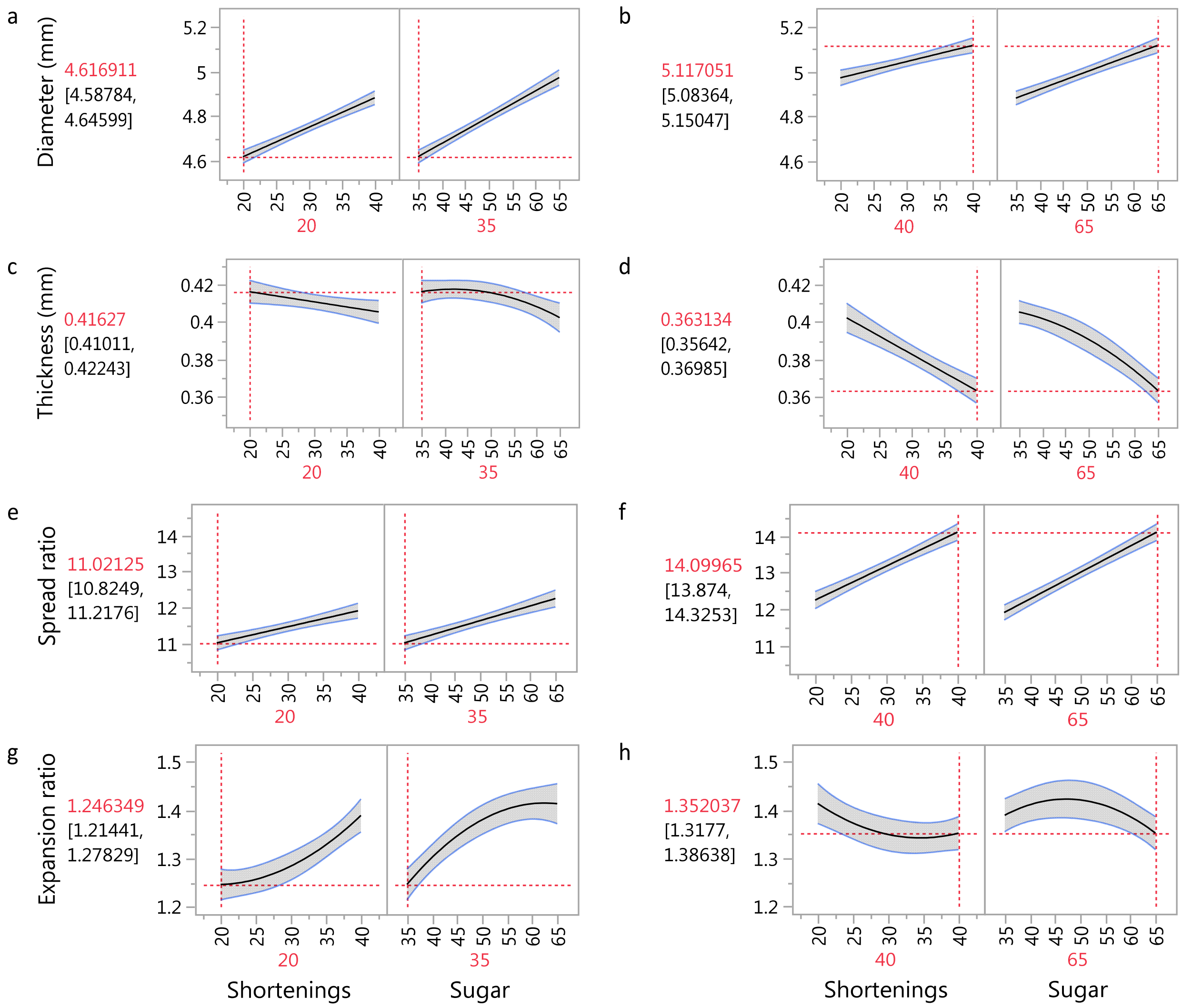

Figure 1 The effect of shortenings and sugar contents (parts of flour) on the shape attributes of biscuits. a,b: diameter, c,d: thickness, e,f: spread ratio, and g,h: expansion ratio. a, c, e, g: at the low contents of each other, and b, d, f, h: at the high contents of each other

Thickness

The thickness of biscuits was significantly affected ($p<0.05$) by shortenings and sugar contents, and their interactions. The effect of shortenings and sugar contents on thickness at the low contents of each other is presented in Fig. 1c and at the high contents of each other is presented in Fig. 1d. At a low concentration of shortenings, the increase in sugar content slightly increased the thickness of biscuits. But in all other cases, the thickness of biscuits decreased with an increase in shortenings and sugar contents. Reduction in the thickness of biscuits could be due to the decrease in viscosity followed by enhanced mobility of dough leading to lateral expansion. In general, the lateral and vertical expansion was in the opposite directions. An inverse relation between the lateral and vertical expansion was reported in previous studies on the effect of sugars and sugar replacement in the dimensions of biscuits (Kweon *et al*., 2009; Laguna *et al*., 2013).

Another important factor affecting the thickness of a biscuit are the number of gases produced before dough setting during baking and the degree of gluten development to hold these gases and vapors released before the setting of dough (Chevallier *et al.,* 2000; Maache-Rezzoug *et al.*, 1998a; van der Sman and Renzetti, 2018). With increasing fat content, the globules of fats in dough surrounding the proteins and grains of starch are more, which isolates them and prevents the formation of polymers (Maache-Rezzoug *et al.*, 1998a). Reduction in the biscuit thickness with an increase in sugar content could also be due to the retarded kinetics of growth of water vapor bubbles (van der Sman and Renzetti, 2018) and the delayed release of chemical leavening (Chevallier *et al.,* 2000) which otherwise would release the gases and contribute to vertical expansion. Also, with an increase in sugar content, water is preferentially used up by sugars, reducing the total amount of water available for the hydration of the gluten (Niroula *et al.,* 2020; Pareyt, *et al.,* 2009) which hinders the ability to expand and hold gases for the vertical expansion of biscuit (Handa *et al.,* 2012; van der Sman and Renzetti, 2018).

Spread ratio

The spread ratio of biscuits was significantly affected ($p<0.05$) by shortenings and sugar contents, and their interactions. The effect of shortenings and sugar contents on thickness at the low contents of each other is presented in Fig. 1e and at the high contents of each other is presented in Fig. 1f. The spread ratio of biscuits increased with increase in shortenings and sugar contents. The increase in spread ratio of biscuits with an increase in shortenings and sugar contents was also reported in previous studies (Maache-Rezzoug *et al.,* 1998a; Pareyt, *et al.,* 2009). The increase in spread ratio indicates a more lateral expansion as compared to vertical expansion. The spread ratio is the combined parameter of the effects on the diameter in response to sugar dissolution and thickness in response to gluten development (Handa *et al.,* 2012; Niroula *et al.,* 2020). In general, larger cookie diameter and higher spread are considered as the desired quality attributes (Niroula *et al.,* 2020; Yamamoto *et al.,* 1996). However, a high spread ratio may not necessarily lead to a desirable quality attribute, sometimes the shrinkage of biscuits could easily result in a high spread ratio (Niroula *et al.,* 2020).

Expansion ratio

The expansion ratio of biscuits is the ratio of the volume of the biscuit piece to the volume of the dough piece before baking (Niroula *et al.,* 2020). It is therefore the combined effect of the vertical expansion (thickness) ratio and square of lateral expansion (diameter) ratio. The physical evaluation of the biscuits based on spread ratio alone could be misleading and therefore expansion ratio of biscuits must also be considered, especially when the recipe is varied (Niroula *et al.,* 2020).

The shortenings and sugar contents had significant ($p<0.05$) direct, interaction, and quadratic effects on the expansion ratio of biscuits. The effect of shortenings and sugar contents on diameter at the low contents of each other is presented in Fig. 1g and at the high contents of each other is presented in Fig. 1h. The increase in shortenings and sugar contents in general increased the expansion ratio but necessarily not always. At low contents of the shortenings and sugar, an increase in the contents of anyone increased the expansion ratio. However, at higher contents of sugar (65 parts), the increase in shortenings content resulted in an initial increase in expansion ratio followed by a slight reduction at very high shortenings contents (35-40 parts). In contrast, when the shortenings content was high (40 parts) the increase in the sugar content initially increased the expansion ratio but was reduced at high sugar contents (50-65 parts).

Sensory attributes

Color and appearance

The surface gloss, smoothness, tints, spread, and vertical expansion were used as the major parameters to describe the appearance of biscuits. The color and appearance of biscuits were significantly affected ($p<0.05$) by contents of shortenings and sugars. The effect of shortenings and sugar contents on the color and appearance of biscuits at the low contents of each other is presented in Fig. 2a and at the high contents of each other is presented in Fig. 2b. The perception scores for color and appearance of biscuits followed a similar pattern; an initial increase and subsequent reduction. The initial increase could be associated with the development of golden yellow-colored biscuits with smooth surfaces and good shine in response to increased shortenings and sugar contents. Fats in foods contribute to the surface smoothness and shiny appearance (Drewnowski & Schwartz, 1990; Manohar & Rao, 1999a), while sugar contributes to the color development and smoothness (Manley, 2011b; Sivam, Sun-Waterhouse *et al.,*, 2010).

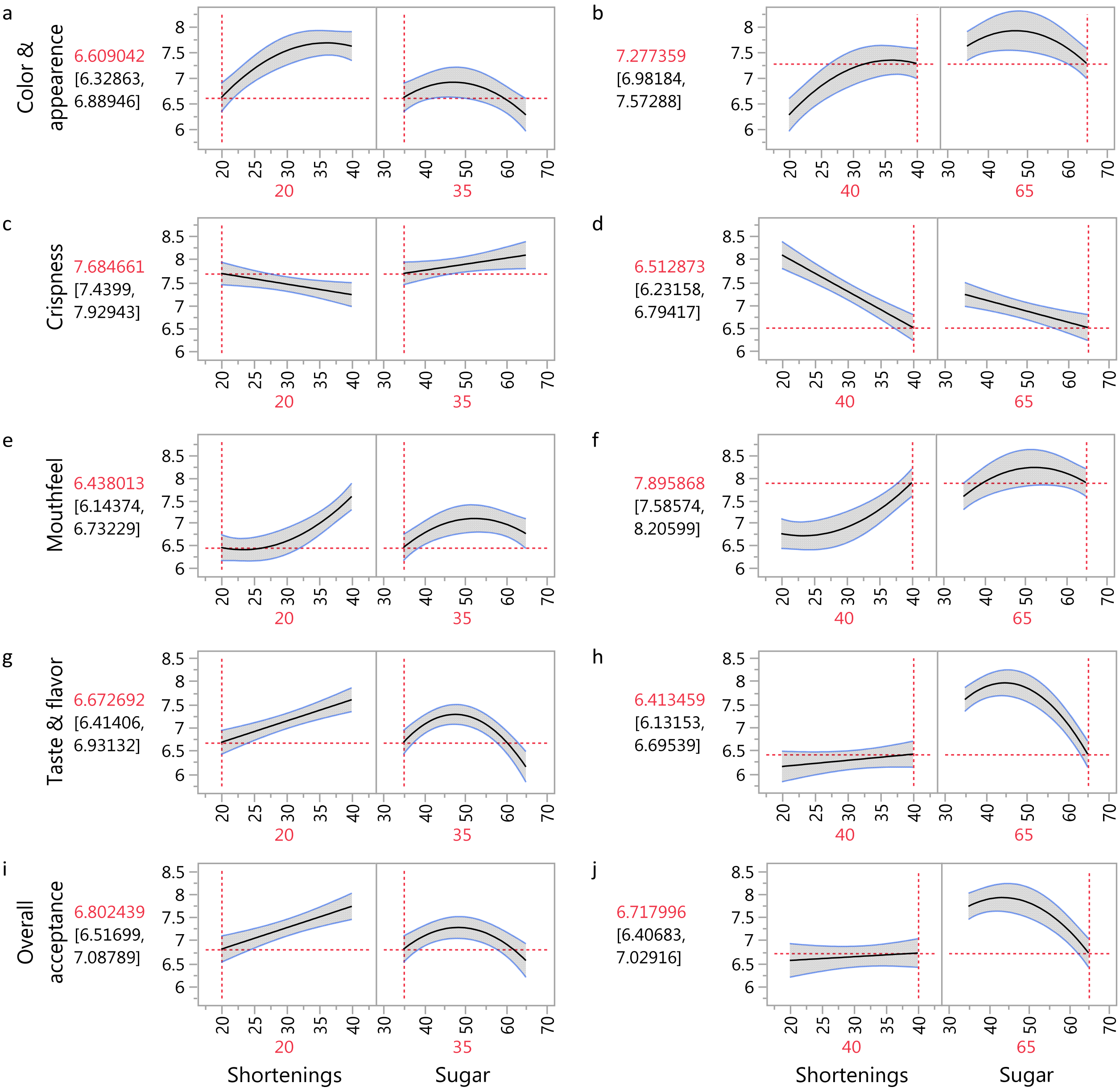

Figure 2 The effect of shortenings and sugar contents (parts of flour) on the sensory attributes of biscuits. a,b: color and appearance, c,d: crispness, e,f: mouthfeel, g,h: taste and flavor, and i,j: overall acceptance. a, c, e, g, i: at the low contents of each other, and b, d, f, h, j: at the high contents of each other

The subsequent reductions in the sensory perception score could be attributed partly to higher spread but lower expansion (vertical) as compared to other samples and partly to the development of dark brown color instead of preferable golden yellow color. The increasing concentration of sugars was reported to result in brown to dark colors due to caramelization and partially due to inversion followed by Maillard reactions during baking (Manley, 2011b; Sivam *et al.,* 2010) . Also, the biscuits prepared with smaller-sized sugars yield darker biscuits than those prepared with normal sugar (Boz, 2019).

Crispness

The crispness of biscuits was significantly affected ($p<0.05$) by the shortenings and sugar contents and their interaction. The effect of shortenings and sugar contents on the crispness of biscuits at the low contents of each other is presented in Fig. 2c and at the high contents of each other is presented in Fig. 2d. The crispness of biscuits was significantly reduced ($p<0.05$) with an increase in fat content. The increase in fat content results in softer dough and the biscuits have a friable structure that is easy to break (Jacob and Leelavathi, 2007; Lai and Lin, 2006; Maache-Rezzoug *et al.,* 1998a). Reduction in the break strength of biscuits with higher fat contents was in agreement with previous studies (Baltsavias *et al.,*1999; Pareyt, *et al.,* 2010; Pareyt *et al.,* 2009; Sudha *et al*., 2007).

The increase in perceptions scores for the crispness of biscuits with an increase in sugar content was possibly associated with the increase in the amount of undissolved sugars and the recrystallization of sugars after baking. The undissolved sugars and recrystallized sugars act as a hardening agent, which makes the product more crumbly and crispy in texture (Kweon *et al.*, 2009; Pareyt and Delcour, 2008; van der Sman and Renzetti, 2018). However, when shortenings content was increased to 40 parts, an increase in sugar content resulted in a decrease in crispness. In fat- or moisture-rich products, sugar acts as a softening agent (Kawai *et al.,* 2014; Lai and Lin, 2006; Maache-Rezzoug *et al.,* 1998a).

Mouthfeel

The mouthfeel of biscuits was significantly affected ($p<0.05$) by shortenings and sugar contents. The effect of shortenings and sugar contents on the mouthfeel of biscuits at the low contents of each other is presented in Fig. 2e and at the high contents of each other is presented in Fig. 2f. The sensory scores for the mouthfeel of biscuits prepared with 20 and 25 pars of shortenings were comparable, but the scores were sharply increased on further increase in shortenings content. Fats act as a lubricant by dispersing themselves in the dough during mixing and preventing continuous network formation of starch and protein to enhance the dispersibility of the product (Mamat and Hill, 2014). This increase in mouthfeel perception scores could also be attributed to the melting of fat, which allows the dispersion of biscuits smoothly in the mouth (Lai and Lin, 2006).

The sensory perception scores for the mouthfeel of biscuits initially increased with an increase in the sugar content to about 50 parts and then decreased. The initial increase in mouthfeel with an increase in the sugar content could be associated with the increase in the melting of sucrose in the mouth. Further increase in the sugar resulted in reduced mouthfeel probably because of incomplete dissolution of sugar crystals. In most short-doughs, there is insufficient water present to dissolve all the added sugar (Manley *et al.*, 2011; Miller and Hoseney, 1997).

Taste and flavor

The taste and flavor of biscuits were significantly affected ($p<0.05$) by shortenings content and sugar content. The effect of shortenings and sugar contents on the taste and flavor of biscuits at the low contents of each other is presented in Fig. 1g and at the high contents of each other is presented in Fig. 1h. Both the shortenings and sugars have been traditionally and industrially used for the taste and flavor enhancement and balance (Abdallah *et al.,* 1998; Besnard *et al.*, 2015; Drewnowski and Almiron-Roig, 2010; Goldfein and Slavin, 2015). The sensory perception scores for the taste and flavor of biscuits increased with an increase in shortenings content. This is in agreement with the findings in previous studies (Sudha *et al.,* 2007; Zoulias *et al.,* 2002). Fats have long been debated as the sixth primary taste of humans; except for an independent perception, there is consistent emerging evidence that fat is the sixth taste primary that consumers carve in food (Besnard *et al.,* 2015; Keast and Costanzo, 2015).

The sensory perception scores for the taste and flavor of biscuits increased with an increase in sugar contents to about 45 parts and then decreased. Besides imparting sweet taste, sugar undergoes caramelization and inversion followed by Maillard browning which contributes towards flavor and color development (Manley, 2011b; Sivam *et al.*, 2010). The reduction in the sensory perceptions for the taste and flavor of biscuits at higher sugar contents (45-65 parts) may be due to the masking of the perception of other taste and flavor components including fats by the increased sweetness intensity (Drewnowski and Schwartz, 1990).

Overall acceptance

The overall acceptance of biscuits was significantly affected ($p<0.05$) by shortenings content and sugar contents and their interaction. The effect of shortenings and sugar contents on the overall acceptance of biscuits at the low contents of each other is presented in Fig. 2i and at the high contents of each other is presented in Fig. 2j. With constant sugar content (35 parts), the increase in fats resulted in a linear increase in the overall acceptance of biscuits. This could be associated with the enhanced mouthfeel and taste and flavor of biscuits with an increase in fat contents. When the fat content was constant (20 parts), the perception scores for the overall acceptance of biscuits increased with an increase in sugar content to about 50 parts and then decreased. This decrease was possibly associated with masking of the taste and flavor of other components by high sweetness. The phenomena were also evidenced by the reduction in the effect of shortenings at high (65 parts) of sugar as shown in Fig, 2j. Overall liking of biscuits is the combined effect of all individual sensory attributes like color, appearance, crispness, mouthfeel, taste, and flavor of biscuits (Abdallah *et al.,* 1998; Drewnowski *et al.,* 1998; Laguna *et al.*, 2013).

Conclusions

The shape and sensory attributes were significantly ($p<0.05$) affected by shortenings and sugar contents. With an increase in shortenings and sugar contents, the diameter and spread ratio of biscuits increased and the thickness decreased. However the expansion ratio increased with an increase in shortenings and sugar contents when the alternate contents were low; but at higher contents of sugar, expansion ratio decreased with increase in shortenings content and at higher contents of shortenings, expansion ratio initially decreased but later increased. As for the sensory attributes, each attribute was affected differently by the shortenings and sugar contents. At constant sugar content, the increase in fats resulted in enhanced mouthfeel, taste and flavor, and overall acceptance of biscuits. While at constant fat contents, the increase in sugar content resulted in an initial increase and subsequent reduction on the sensory attributes except crispness. And at low fat content (20 parts), an increase in sugar content increased the scores for crispness, while at high fat content (40 parts), the scores for crispness decreased with increase in sugar content. This study revealed that the increase in shortenings and sugar contents does not necessarily increase the sensory perceptions of the biscuits; an attribute could be enhanced while the other could be compromised. A good balance between these two components is essential for the optimum biscuit quality.

Acknowledgement

The authors would like to thank Nagarik College for providing all essential materials and amenities for this study.

References

Abboud, A. M., & Hoseney, R. C. (1984). Differential scanning calorimetry of sugar cookies and cookie doughs. Cereal Chemistry, 61(1), 34–37.

Abdallah, L., Chabert, M., Le Roux, B., & Louis-Sylvestre, J. (1998). Is pleasantness of biscuits and cakes related to their actual or to their perceived sugar and fat contents? Appetite, 30(3), 309–324. https://doi.org/10.1006/APPE.1997.0143

Baltsavias, A., Jurgens, A., & Van Vliet, T. (1999). Fracture Properties of Short-Dough Biscuits: Effect of Composition. Journal of Cereal Science, 29(3), 235–244. https://doi.org/10.1006/JCRS.1999.0249

Besnard, P., Passilly-Degrace, P., & Khan, N. A. (2015). Taste of fat: A sixth taste modality? Physiological Reviews, 96(1), 151–176. https://doi.org/10.1152/physrev.00002.2015

Boz, H. (2019). Effect of flour and sugar particle size on the properties of cookie dough and cookie. Czech Journal of Food Sciences, 37(2), 120–127. https://doi.org/10.17221/161/2017-CJFS

Chevallier, S., Colonna, P., & Bule, A. (2000). Physicochemical behaviors of sugars, lipids, and gluten in short dough and biscuit. Journal of Agricultural and Food Chemistry, 48, 1322–1326. https://doi.org/10.1021/jf990435+

Davis, A. (1995). Functionality of sugars: physicochemical interactions in foods. American Journal of Clinical Nutrition, 62(suppl), 170S-177S.

Drewnowski, A., & Almiron-Roig, E. (2010). Human Perceptions and Preferences for Fat-Rich Foods. In J.-P. Montmayeur & J. le Coutre (Eds.), Fat Detection: Taste, Texture, and Post Ingestive Effects (pp. 265–291). Boca Raton, FL, US: CRC Press/Taylor & Francis Group, LLC.

Drewnowski, A., Nordensten, K., & Dwyer, J. (1998). Replacing sugar and fat in cookies: Impact on product quality and preference. Food Quality and Preference, 9(1–2), 13–20. https://doi.org/10.1016/S0950-3293(97)00017-7

Drewnowski, A., & Schwartz, M. (1990). Invisible fats: Sensory assessment of sugar/fat mixtures. Appetite, 14(3), 203–217. https://doi.org/10.1016/0195-6663(90)90088-P

Drewnowski, A., Shrager, E. E., Lipsky, C., Stellar, E., & Greenwood, M. R. C. (1989). Sugar and fat: Sensory and hedonic evaluation of liquid and solid foods. Physiology & Behavior, 45, 177–183. https://doi.org/10.1016/0031-9384(89)90182-0

Glickman, M. (1991). Hydrocolloids and the search for the “oil grail.” Food Technology, 45, 94–101.

Goldfein, K. R., & Slavin, J. L. (2015). Why Sugar Is Added to Food: Food Science 101. Comprehensive Reviews in Food Science and Food Safety, 14(5), 644–656. https://doi.org/10.1111/1541-4337.12151

Handa, C., Goomer, S., & Siddhu, A. (2012). Physicochemical properties and sensory evaluation of fructoligosaccharide enriched cookies. Journal of Food Science and Technology, 49(2), 192–199. https://doi.org/10.1007/s13197-011-0277-4

Jacob, J., & Leelavathi, K. (2007). Effect of fat-type on cookie dough and cookie quality. Journal of Food Engineering, 79(1), 299–305. https://doi.org/10.1016/J.JFOODENG.2006.01.058

Kawai, K., Toh, M., & Hagura, Y. (2014). Effect of sugar composition on the water sorption and softening properties of cookie. Food Chemistry, 145, 772–776. https://doi.org/10.1016/J.FOODCHEM.2013.08.127

Keast, R. S., & Costanzo, A. (2015). Is fat the sixth taste primary? Evidence and implications. Flavour, 4, 5. https://doi.org/10.1186/2044-7248-4-5

Kweon, M., Slade, L., Levine, H., Martin, R., & Souza, E. (2009). Exploration of sugar functionality in sugar-snap and wire-cut cookie baking: implications for potential sucrose replacement or reduction. Cereal Chemistry, 86(4), 425–433. https://doi.org/10.1094/CCHEM-86-4-0425

Laguna, L., Vallons, K. J. R., & Jurgens, A. (2013). Understanding the effect of sugar and sugar replacement in short dough biscuits. Food and Bioprocess Technology, 6, 3143–3154. https://doi.org/10.1007/s11947-012-0968-5

Lai, H. M., & Lin, T. C. (2006). Bakery Products: Science and Technology. In Y. H. Hui (Ed.), Bakery Products: Science and Technology (pp. 3–68). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470277553.CH1

Maache-Rezzoug, Z., Bouvier, J., Allaf, K., & Patras, C. (1998a). Effect of Principal Ingredients on Rheological Behaviour of Biscuit Dough and on Quality of Biscuits. Journal of Food Engineering, 35(1), 23–42. https://doi.org/10.1016/S0260-8774(98)00017-X

Maache-Rezzoug, Z., Bouvier, J. M., Allaf, K., & Patras, C. (1998b). Study of mixing in connection with the rheological properties of biscuit dough and dimensional characteristics of biscuits. Journal of Food Engineering, 35(1), 43–56. https://doi.org/10.1016/S0260-8774(98)00018-1

Mamat, H., & Hill, S. E. (2014). Effect of fat types on the structural and textural properties of dough and semi-sweet biscuit. Journal of Food Science and Technology, 51(9), 1998–2005. https://doi.org/10.1007/s13197-012-0708-x

Manley, D. (2011a). Setting the scene: A history and the position of biscuits. In D. Manley (Ed.), Manley's Technology of Biscuits, Crackers and Cookies: Fourth Edition (pp. 1–9). Elsevier Ltd. https://doi.org/10.1533/9780857093646.1

Manley, D. (2011b). Sugars and syrups as biscuit ingredients. In D. Manley (Ed.), Manley's technology of biscuits, crackers and cookies (4th ed., pp. 143–159). Cambridge, England: Woodhead Publishing Limited. https://doi.org/10.1533/9780857093646.2.143

Manley, D., Pareyt, B., & Delcour, J. A. (2011). Short dough biscuits. In D. Manley (Ed.), Manley's technology of biscuits, crackers and cookies (4th ed., pp. 331–346). Cambridge, England: Woodhead Publishing Limited. https://doi.org/10.1533/9780857093646.3.331

Manohar, R. S., & Rao, P. H. (1999a). Effect of emulsifiers, fat level and type on the rheological characteristics of biscuit dough and quality of biscuits. Journal of the Science of Food and Agriculture, 79(10), 1223–1231. https://doi.org/10.1002/(SICI)1097-0010(19990715)79:10

Manohar, R. S., & Rao, P. H. (1999b). Effect of mixing method on the rheological characteristics of biscuit dough and the quality of biscuits. European Food Research and Technology, 210, 43–48. https://doi.org/10.1007/s002170050530

Miller, R. A., & Hoseney, R. C. (1997). Factors in Hard Wheat Flour Responsible for Reduced Cookie Spread. Cereal Chemistry, 74(3), 330–336. https://doi.org/10.1094/CCHEM.1997.74.3.330

Niroula, A., Pokharel, A., & Acharya, J. (2020). Effect of Type of Sugar and Dough Relaxation Time on the Shape Characteristics of Biscuits. Journal of Food Science and Technology Nepal, 12, 25–30.

Pareyt, B., Brijs, K., & Delcour, J. A. (2009). Sugar-snap cookie dough setting: the impact of sucrose on gluten functionality. Journal of Agricultural and Food Chemistry, 57, 7814–7818. https://doi.org/10.1021/jf9010774

Pareyt, B., Brijs, K., & Delcour, J. A. (2010). Impact of Fat on Dough and Cookie Properties of Sugar-Snap Cookies. Cereal Chemistry, 87(3), 226–230. https://doi.org/10.1094/CCHEM-87-3-0226

Pareyt, B., & Delcour, J. A. (2008). The role of wheat flour constituents, sugar, and fat in low moisture cereal based products: a review on sugar-snap cookies. Critical Reviews in Food Science and Nutrition, 48(9), 824–839. https://doi.org/10.1080/10408390701719223

Pareyt, B., Talhaoui, F., Kerckhofs, G., Brijs, K., Goesaert, H., Wevers, M., & Delcour, J. A. (2009). The role of sugar and fat in sugar-snap cookies : Structural and textural properties. Journal of Food Engineering, 90(3), 400–408. https://doi.org/10.1016/j.jfoodeng.2008.07.010

Sivam, A. S., Sun-Waterhouse, D., Quek, S., & Perera, C. O. (2010). Properties of Bread Dough with Added Fiber Polysaccharides and Phenolic Antioxidants: A Review. Journal of Food Science, 75(8), R163. https://doi.org/10.1111/J.1750-3841.2010.01815.X

Slade, L., & Levine, H. (1994). Structure-function relationships of cookie and cracker ingredients. In H. Faridi (Ed.), The Science of Cookie and Cracker Production (pp. 23–141). New York: Chapman and Hall.

Sudha, M. L., Srivastava, A. K., Vetrimani, R., & Leelavathi, K. (2007). Fat replacement in soft dough biscuits: Its implications on dough rheology and biscuit quality. Journal of Food Engineering, 80(3), 922–930. https://doi.org/10.1016/J.JFOODENG.2006.08.006

van der Sman, R. G. M., & Renzetti, S. (2018). Understanding functionality of sucrose in biscuits for reformulation purposes. Critical Reviews in Food Science and Nutrition, 59(14), 2225–2239. https://doi.org/10.1080/10408398.2018.1442315

Yamamoto, H., Worthington, S. T., Hou, G., & Ng, P. K. W. (1996). Rheological properties and baking qualities of selected soft wheats grown in the United States. Cereal Chemistry, 73(2), 215–221.

Zoulias, E. I., Oreopoulou, V., & Kounalaki, E. (2002). Effect of fat and sugar replacement on cookie properties. Journal of the Science of Food and Agriculture, 82(14), 1637–1644. https://doi.org/10.1002/jsfa.1230

Zoulias, E. I., Piknis, S., & Oreopoulou, V. (2000). Effect of sugar replacement by polyols and acesulfame-K on properties of low-fat cookies. Journal of the Science of Food and Agriculture, 80(14), 2049–2056. https://doi.org/10.1002/1097-0010(200011)80:14%3C2049::AID-JSFA735%3E3.0.CO;2-Q

Zydenbos, S., Humphrey-Taylor, V., & Wrigley, C. (2004). Cookies, biscuits, and crackers: The diversity of products. In C. Wrigley (Ed.), Encyclopedia of Grain Science (pp. 313–317). NSW, Australia: Elsevier. https://doi.org/10.1016/B0-12-765490-9/00019-7

♦♦