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Effects of partial sugar replacement on the physicochemical and sensory properties of low sugar cookies

*Ho, L.-H. and Pulsawat, M. M.

Department of Food Industry, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200, Besut, Terengganu, Malaysia

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Abstract

The aim of the present work was to produce low sugar cookies by partial substitution with a sugar replacer (*i.e.* maltitol, sorbitol, and isomalt) for sucrose. Four different types of cookies were prepared. Sucrose was replaced by maltitol, sorbitol, and isomalt at 50% level (based on relative degree of sweetness of sucrose) to produce CMAL50, CSOR50, and CISO50, respectively. Cookies that contained sucrose represented the control. All the cookies produced were analysed for chemical properties, physical properties, and sensorial acceptance. The chemical analysis results indicated that CMAL50, CSOR50, and CISO50 had higher moisture, crude fibre, and the total carbohydrate content, but with lower ash, crude protein, crude fat, calories, and total sugar content than the control. CSOR50 showed the lowest total sugar content; thus, could be denoted as 'low sugar' cookies. Cookies containing maltitol and isomalt presented good physical quality. The hardness value of cookies decreased with 50% substitution of sorbitol and isomalt for sucrose. CISO50 showed the lowest lightness and yellowness values than other cookie samples. The sensory evaluation results showed that the cookies incorporated with maltitol and isomalt did not influence the overall acceptability of cookies. In conclusion, the replacement of sucrose with maltitol, sorbitol, and isomalt could reduce sugar and daily calorie intake. However, sorbitol substitution at 50% level is feasible to produce 'low sugar' cookies, and this cookie could provide benefits to weight and health-conscious consumers.

Introduction

Bakery products are becoming increasingly popular around the world due to their availability, economical cost, convenience, and good taste (Nagi *et al.,* 2012). Among bakery products, cookies represent the largest category of snack items that are widely consumed all over the world to satisfy hunger (Amin *et al.,* 2016). Cookies are generally produced from a mixture of flour, fat, sugar, and may sometimes include water and other ingredients to form the dough. Sucrose is the main ingredient of cookies to provide sweetness, humectancy, and texture as well as extending their shelf life (Ghosh and Sudha, 2012). In addition, sucrose also influences physical properties (*i.e.* dimension, hardness, colour, and surface finish) and taste of the baked products (Gallagher *et al.,* 2003). In cookies, spread ratio is an important parameter to determine the dimension of the baked product. Higher spread ratio is considered most desirable for good quality cookies (Mudgil, 2017). Spread ratio is influenced by the type of sugar used because sugar melts and turns into a liquid, thus making the batter more viscous while adding the spread during the baking process (Mckemie, 2008). However, the intake of large amounts of sucrose has been associated with several serious health problems such as obesity and diabetes mellitus.

Nowadays, the increasing demand for natural products, coupled with consumers growing concern about their health has prompted the food industry to search for healthier products. Consumers look for products that have low calories, low sugar content, sugar-free, and high in protein and dietary fibre (Amin *et al.,* 2016). The search for healthier products has led to the development of alternative sweetening agents with low energy value (Ghosh and Sudha, 2012). Many natural and artificial sweeteners have been developed to substitute sugar in bakery products. Polyol is an example of a natural sweetener used in baked products. Polyols are also known as sugar alcohols that are neither alcohol nor sugar. It is a carbohydrate in hydrogenated form in which the carboxyl group either ketone or aldehyde has been reduced to a primary or secondary hydroxyl group, hence alcohol. They have the general formula of $H(HCHO)_{n+1}H$ as compared to sugars that have $H(HCHO)_nHCO$ (Bhise and Kaur, 2013).

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*Corresponding author.
Email: holeehoon@unisza.edu.my

Examples of bulk sweeteners that belong to polyol group are sorbitol (E420), maltitol (E965), isomalt (E953), xylitol (E967), mannitol (E421), lactitol (E966), erythritol, and hydrogenated starch hydrolysates (HSHs). They have less energy weight and slightly reduced sweetness as compared to sucrose (Ghosh and Sudha, 2012). The intake of polyols is restricted to 30 g per day for children, and 40 - 50 g per day for adults in order to avoid gastrointestinal discomfort (Deis and Kearsley, 2012).

Maltitol is a disaccharide sugar alcohol produced by catalytic hydrogenation of maltose obtained from starch. Maltitol is characterised with a sweetness similar to that of sucrose. It has 75 - 90% of the sweetness of sucrose and nearly identical properties, with a relative sweetness of 0.9. The level of sweetness of maltitol allows it to be used as a table sugar replacer, and an alternative sweetening agent without being mixed with other sweeteners. It is often used at approximately one-for-one replacement for sucrose in baked products. Maltitol is incompletely absorbed and metabolised by the body, and consequently contributes lower calories than most sugars and has a lesser effect on blood glucose level. Isomalt is a disaccharide formed from glucose and mannitol. Isomalt has similar characteristics to sucrose as it is odourless, crystalline, possesses a pure sweet taste that does not cause any aftertaste; yet it is non-hygroscopic. Its sweetening power falls between 0.45 and 0.6 times of sucrose and is often used to make sugar-free baked products (Ghosh and Sudha, 2012). Sorbitol is a type of polyols that is obtained by the reduction of glucose through changing the aldehyde group to a hydroxyl group. Sorbitol has a relative sweetness of 0.6 times that of sucrose. It is highly soluble in water and often works as a humectant that does not allow baked goods to dry out. Hence, sorbitol is a useful ingredient in the formulation of sugar-free cookies, cakes, and muffins (Ghosh and Sudha, 2012).

According to Nagi *et al.* (2012), the low calorie products could be developed by adding bulking agents that possess a high moisture absorption ability resulting in the reduction of calories by 33%. Amin *et al.* (2016) have developed high protein and sugar-free cookies fortified with pea flour, soya bean flour, and oat flakes. According to Mckemie (2008), isomalt causes positive influences on the appearance and texture, enhancing the flavours, and extending the shelf life of the baked products. Zoulias *et al.* (2000) reported that partial replacement (35%) of maltitol for sucrose in cookie preparation resulted in a similar diameter with cookies made of 100% sucrose but with a bigger diameter than the cookies made of fructose due to maltitol solubility that is similar to sucrose. According to Deis and Kearsley (2012), the use of sorbitol in the cookies resulted in a soft cookie texture. The present work thus focuses on the effect of sugar replacement by polyols (*i.e.* maltitol, sorbitol, and isomalt) for sucrose in cookie making. The proximate composition, textural, and physical properties of the prepared cookies were studied. Furthermore, the sensory evaluation of the cookies was also carried out.

Materials and method

Materials

Bakery ingredients such as wheat flour, salted butter, baking powder, sucrose, and eggs were purchased from Mydin Mohamed Holdings Bhd., Kuala Terengganu, Terengganu, Malaysia. The sorbitol and isomalt were obtained from 1 Stop Bakery.com, Jatujak, Bangkok, Thailand, and maltitol was procured from Sim Company Sdn. Bhd. Penang, Malaysia. All reagents used in the present work were of analytical grade.

Production of cookies

Cookies were produced following the method described by Ho and Latif (2016) with slight modifications. The cookies were prepared using wheat flour, sucrose, or polyols (*i.e.* maltitol, sorbitol, or isomalt), salted butter, baking powder, vanilla essence, and eggs. The formula used to prepare the cookies is shown in Table 1. Maltitol, sorbitol, and isomalt replaced the sucrose at a level of 50% for the preparation of CMAL50, CSOR50, and CISO50, respectively. Cookies formulated without polyols served as control. The weight of the polyols was calculated based on their relative sweetness to sucrose (0.9, 0.6, and 0.5).

Table 1. Formulation of cookies.

Ingredient (g)	Control	CMAL50	CSOR50	CISO50
Wheat flour	280	280	280	280
Salted butter	120	120	120	120
Baking powder	4.2	4.2	4.2	4.2
Sucrose	100	50	50	50
Polyols	-	55.55	83.33	100
Egg	50	50	50	50

'-' indicates without ingredient. CMAL50: sucrose replaced with 50% maltitol; CSOR50: sucrose replaced with 50% sorbitol; and CISO50: sucrose replaced with 50% isomalt.

Eggs were creamed until it became fluffy with sucrose or polyols for 5 min by using a hand mixer (5 Speeds Turbo HR1459, Philips, Malaysia). Then, the salted butter was added into the mixture and continued to cream for 7 min until it formed a meringue. The next step included adding pre-sieved blended wheat flour and baking powder that was then thoroughly mixed. The soft dough was thoroughly kneaded for 4 min to obtain a homogeneous dough. Then, the dough was manually sheeted to a thickness of 5 mm using a rolling pin. The sheeted dough was cut with a 35 mm diameter cookie cutter. The shaped doughs were then placed on greased baking trays at a proper distance. All the prepared doughs were baked in an electric multideck baking oven (Schneider Electric, MBE-203E-Z, Paris, French) at 180°C for 15 min. The cookies were cooled at room temperature (25 ± 1°C) for 30 min before being packed into zipper bag and stored in an airtight food storage plastic container at room temperature (25 ± 1°C) for further evaluation.

Determination of proximate composition

The proximate compositions of the cookies were determined following the official method as proposed by the Association of Official Agricultural Chemists (AOAC, 1995). The oven drying method (AOAC Official Method 977.11) was used to analyse moisture content, however the Kjeldahl method (AOAC Official Method 955.04) was referred when analysing crude proteins. The Soxhlet method (AOAC Official Method 960.39) was used to determine crude fat, while the dry ashing method (AOAC Official Method 923.03) was used to determine the ash content. Finally, the gravimetric methods (AOAC Official Method 991.43) was used to analyse crude fibre contents.

Total carbohydrate and energy estimation

The total carbohydrate content of the cookies was estimated by calculation [total carbohydrate (% wet basis) = 100% - % (moisture + ash + crude protein + crude fat)] (BeMiller and Low, 1998). The energy of the cookies was calculated by multiplying the factor values; 1 g of crude protein or carbohydrate provides 4 kcal of energy, and 1 g of crude fat provides 9 kcal of energy) (Nielsen and Metzger, 2003).

Determination of total sugar

Total sugar content of the cookies was determined following the phenol sulphuric acid method as proposed by Dahri *et al.* (2017). Approximately 50 mg of powdered cookies was extracted with 5 mL of ethanol (80% v/v) by heating at 95°C in a water bath for 10 min. The mixture solution was centrifuged at 2,500 rpm for 5 min. The extraction was repeated twice. Approximately 1 mL of phenol solution (2%) and 2 mL of concentrated sulphuric acid were added into 0.5 mL of the ethanol extract. The mixture was thoroughly vortexed, and incubated for 30 min in a water bath at 22°C. The mixture of the glucose, galactose, and fructose was used as standard solution. The absorbance of the prepared sample extract and standard solution was measured using a UV-VIS spectrophotometer (Shimadzu UV-1601PC, Japan) at 490 nm.

Colour measurement

The colour of the cookies was measured according to the Commission Internationale de I 'Eclairage (CIE) $L^*a^*b^*$ scale. Colorimeter (Konica Minolta, Chroma Meter CR-400, Tokyo, Japan) was used to determine the L^* [Lightness (L^* = 100; white, L^* = 0; black)], Chroma a* [green chromaticity (-60) to red (+60)], and Chroma b* [blue chromaticity (-60) to yellow (+60)] space values.

Diameter, height, and spread ratio measurement

The measurement of diameter, height, and spread ratio of the cookies was conducted after baking and cooling at ambient temperature for 30 min. The diameter was measured with a calliper after baking. To determine the diameter of cookies, four cookies were randomly picked and placed next to one another and the total diameter was measured. This was then followed by rotating the cookies at a 90° angle and the new diameter was measured. This step was repeated for angles of 180, 270, and 360°. The mean value of diameter was recorded. To determine the height, four cookies were stacked above one another and restacked four times. The mean value of the height was recorded. To determine the spread ratio, the equation as follows: diameter of cookies divided by the height of cookies, was used.

Hardness determination

The hardness of cookies was analysed using a texture analyser (Stable Micro System, TA.XT2i, Surrey, UK). The instrument was equipped with 2 kg load cell weight (AACC, 2000). The cookies were measured using a sharp cutting bladed probe type HDP/BS blade set at a pre-test speed of 2 mm/s, test speed of 1 mm/s, post-test speed of 5 mm/s, and 3 mm of compression distance. The hardness of the cookies was analysed using Texture Expert Version 1.05 Software (Stable Micro System Ltd., Surrey, UK).

Sensory evaluation

The sensory attributes of the produced cookies were performed by 30 semi-trained panellists consisting of students and staff of the Faculty Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Malaysia. The cookie sensory was evaluated using a 7-point hedonic scale (1 = dislike

2 = dislike moderately; 3 = dislike slightly; 4 = neither like nor dislike; 5 = like slightly; 6 = like moderately; and 7 = like very much) (Watts *et al.,* 1989). The sensory evaluation was conducted on the freshly baked cookies. The fresh cookie sample was placed onto the identical plate and coded with different 3-digit numerical codes. Each sample was presented to the panellists in a randomised order so that each sample appeared in a particular position for an equal number of times. Each panellist was served with a tray containing a plate of labelled cookies, a cup of 300 mL drinking water, and a sensory form sheet. They were asked to rate the samples based on a scale for each of the following attributes; colour, aroma, mouthfeel, crispiness, and overall acceptability.

Statistical analysis

Statistical analysis was conducted using Statistical Package for the Social Science (SPSS) 20.0 software (SPSS Inc., Chicago, IL, USA). The obtained results were expressed as means ± the standard deviations of three individual replicates ($n = 3$). The data was subjected to one-way analysis of variance (ANOVA). The significant differences among the mean values of the samples were determined by Duncan's multiple range test (DMRT) at a significance level of $p < 0.05$.

Results and discussion

Proximate composition of cookies

The proximate composition of cookies (*i.e.* Control, CMAL50, CSOR50, and CISO50) is shown in Table 2. The replacement of polyols (*i.e.* maltitol or sorbitol or isomalt) for sucrose was at a 50% level that significantly ($p < 0.05$) increased the moisture content of cookies as compared to the control cookies made with 100% sucrose. Among the cookies, CSOR50 presented substantial increase in moisture content. An increase in moisture content was due to the sorbitol that acted as a humectant wherein it held in moisture tightly and did not allow the cookies to dry out (Ghosh and Sudha, 2012). The results obtained in the present work are in agreement with the reports by Majeed *et al.* (2018), whereby sorbitol is more hygroscopic in nature than maltitol. Polyols such as maltitol, sorbitol, and isomalt are good water binders in a food system due to the presence of hydrophilic characteristics. These characteristics of polyols help to retain moisture in foods. Moisture content influences the shelf life of the baked goods. The products will have longer shelf life if they are stored in appropriate packaging and proper storage conditions. However, microorganisms cannot grow well on cookies that contain polyols as they do on sucrose (Majeed *et al.,* 2018), hence the shelf life of the cookies would be extended.

Replacement of sucrose with polyols at 50% level was found to be significant ($p < 0.05$) since there was a decrease in the ash content (0.81, 0.60, and 0.64 for CMAL50, CSOR50, and CISO50, respectively) of cookies as compared to the control (100% sucrose) (1.32%). According to Ho *et al.* (2018), the total percentage of ash will give an idea on the mineral content in the composite cookies. This indicated that cookies made of polyols contained lower mineral content than the control cookies (cookies made of sucrose). This was due to the lower ash content of polyols (*i.e.* maltitol, sorbitol, and isomalt) as compared to the sucrose.

The partial substitution of maltitol, sorbitol, and isomalt for sucrose did not affect the protein content of the cookies (*i.e.* CMAL50, CSOR50, and CISO50). Crude protein ranged from 7.24 - 8.33%.

Table 2. Proximate composition and total sugar of cookies.

Composition (%)	Control	CMAL50	CSOR50	CISO50
Moisture	2.41 ± 0.06^{c}	2.95 ± 0.08^{ab}	3.14 ± 0.10^{a}	2.87 ± 0.10^{b}
Ash	1.32 ± 0.02^{a}	0.81 ± 0.00^{b}	0.60 ± 0.00^{c}	0.64 ± 0.03^{c}
Crude protein	8.33 ± 0.88^{a}	7.44 ± 0.44^{a}	7.24 ± 0.16^{a}	7.36 ± 0.08^{a}
Crude fat	21.11 ± 0.10^{a}	20.43 ± 0.07^{ab}	20.05 ± 0.70^{b}	18.51 ± 0.02^{c}
Crude fibre	1.44 ± 0.07^{b}	3.16 ± 0.13^{a}	2.19 ± 0.06^{ab}	3.30 ± 0.84^{a}
Total carbohydrate*	66.84 ± 0.83^{c}	68.37 ± 0.45^{bc}	68.98 ± 0.76^{ab}	70.63 ± 0.07^{a}
Calories* (Kcal/100 g dry matter)	490.63 ± 0.66^{a}	487.11 ± 0.69^{a}	485.27 ± 3.90^{a}	478.49 ± 0.40^{b}
Total sugar	11.92 ± 0.83^{a}	7.74 ± 0.68^{b}	4.17 ± 0.08^{c}	7.93 ± 0.84^{b}

Data are means ± standard deviations of two replications ($n = 2$). Means with different superscripts within the same row are significantly different from each other ($p < 0.05$). *Values obtained by calculation; CMAL50: cookies with 50% maltitol; CSOR50: cookies with 50% sorbitol; and CISO50: cookies with 50% isomalt.

This proved that the polyols were not a source of protein, but they were reduced-calorie carbohydrates. In addition, medium protein flour such as all-purpose flour has low protein content (9.5 - 10.5%) (Malayan Flour Mills Bhd., 2017) and was used to prepare the cookies.

Cookies made of sorbitol and isomalt (CSOR50 and CISO50, respectively) had a significantly ($p < 0.05$) lower crude fat content (18.51 - 20.05%). Fat plays an important role in influencing the food texture by forming the structure of crystalline networks and disruption of the structure by interfering with the non-fat network. Moreover, the addition of polyols to food can inhibit crystal formation, thus imparting creaminess and smoothness on the food products (Rios *et al.,* 2014). In addition, the lower crude fat content of cookies containing polyols (*i.e.* CMAL50, CSOR50, and CISO50), which was more than the control cookies, was largely affected by the high moisture content of the cookies. According to Ho *et al.* (2013), the fat uptake is associated with the moisture content of the final product, wherein free water molecules served as an important substance in the formation of a barrier coating during heating, causing a reduction in water loss. Thus, the free water can reduce oil penetration into food. Therefore, the use of polyols in cookie making could reduce fat content of cookies.

In cookies, polyols were found to significantly increase the crude fibre content (2.19 - 3.30%) of the baked products. Polyols have a property similar to fibre that had low digestible carbohydrates. Low digestible carbohydrates are carbohydrates that are not incompletely absorbed in the small intestine but are at least partly fermented by good bacteria in the large intestine (Grabitske and Slavin, 2009). This is in agreement with results from Majeed *et al.* (2018) who reported that the crude fibre content of the cookies increased as the sucrose were replaced by sorbitol at levels of 0 - 12.5%.

Replacement of sugar with maltitol (CMAL50), sorbitol (CSOR50), and isomalt (CISO50) at a 50% level indicated that the total carbohydrate content of the cookies increased. The CSOR50 and CISO50 showed significantly ($p < 0.05$) higher carbohydrate content (68.98 and 70.63%, respectively) than the control (66.84%). The obtained results in the present work was in agreement with a previous study by Aggarwal *et al.* (2016), who reported that an increased total carbohydrate content of the reduced-calorie biscuits is due to the addition of maltitol that is calculated as part of a carbohydrate. Bhise and Kaur (2013) had reported that polyols are types of carbohydrates. Thus, they can be used in the same amount (volume-for-volume) as sucrose and can be added in bulk to foods. Therefore, substitution of sugar replacers for sucrose to the formulation of cookie preparation could increase the amount of carbohydrate content of cookies.

Cookies containing isomalt (CISO50) was found with significantly ($p < 0.05$) the lowest calorie content (478.49 kcal/100 g). The obtained results in the present work was in agreement with previous work done by Deis and Kearseley (2012), which reported that the isomalt had a lower caloric value (2 kcal/g) than maltitol and sorbitol (2.1 and 2.6 kcal/g, respectively). The general lower value of calories in CISO50 as compared to the control cookies was due to the relatively reduced absorption of isomalt from the small intestine, and could provide about 2 kcal/g to the general calorie pool. According to Jeffery *et al.* (2012), polyols provide fewer calories about 1.5 to 3 kcal/g as compared to 4 kcal/g of sucrose. Thus, replacement of maltitol, sorbitol, and isomalt for sucrose can help to reduce the calorie content in cookies.

The result of total sugar of cookies is presented in Table 2. Cookies containing maltitol, sorbitol, and isomalt (CMAL50, CSOR50, and CISO50, respectively) indicated significantly ($p < 0.05$) lower total sugar (7.74, 4.17, and 7.93%, respectively) than the control cookies (11.92%). Among the cookies, CSOR50 showed the lowest total sugar content (4.17%) than the other cookie samples. The obtained results in the present work are in agreement with previous work done by Jang *et al.* (2015) who reported that the semi-dried jerkies made of sorbitol showed significantly lower total sugar content than the control. In general, sucrose is known to contain the sugar content of 1.0 °brix, while maltitol, sorbitol, and isomalt have sugar contents of 0.8 - 0.9, 0.5 - 0.6, and 0.5 °brix, respectively. Therefore, maltitol, sorbitol, and isomalt produced cookies with lower sugar content. Based on Food Act 1983 (Act 281) and Regulations (Laws of Malaysia, 2017), the product should be below 5 g per 100 g (5%) for solid food in order to claim it as 'low sugar'. Hence, this value (4.17%) indicates that the cookies made of sorbitol can be categorised as 'low sugar' cookies. Thus, cookies prepared by partial substitution of sorbitol for sucrose at 50% (CSOR50) can be claimed as 'low sugar' cookies. In conclusion, the total sugar content of the cookies could be reduced by partial substitution of polyols such as maltitol, sorbitol, and isomalt for sucrose.

Physical properties of cookies

Results of the physical properties of cookies including diameter, height, spread ratio, and hardness are presented in Table 3. In general, cookies are made of soft wheat flour that has low gluten content and strength. These properties produce collapsible film instead of an elastic network dough during mixing. As a result, cookies go through an expansion followed by a collapse during baking, while the elastic network would exhibit elastic shrinkage after expansion therefore there is no abrupt increase in diameter (Zoulias *et al.,* 2000). Among the prepared cookies, cookies made of 50% sorbitol (CSOR50) showed the highest diameter (15.33 mm) followed by CISO50 (15.18 mm), CMAL50 (14.82 mm), and the control (14.72 mm). Cookies containing polyols presented substantial increase in diameter that was attributed to higher solubility of polyols as compared to sucrose. Sorbitol presented the highest solubility of 73% dissolved solid (DS) at 20°C, followed by sucrose (67% DS), maltitol (60% DS), and isomalt (25% DS). The high solubility characteristic of polyols could maintain their dissolved nature longer during baking and would facilitate the flow of the dough. Therefore, the substitution of polyols for sucrose decreased the dough viscosity and facilitated the flow of the dough in the early stages of baking. Low dough viscosity contributes to larger cookie diameter. A positive correlation had been obtained between moisture content (Table 2) and diameter (Table 3) of the prepared cookies, whereby CSOR50 showed the highest value of moisture and diameter. This was attributed to the high water absorption characteristic of sorbitol that had attracted more water and thus decreased the dough viscosity, leading to an increase of the diameter of the cookies. In contrast, Ghosh and Sudha (2012) recorded that cookies prepared with maltitol showed greater diameter than cookies prepared with sorbitol.

In general, the height of the baked products resulted from the gluten development which led to expansion during baking. However, in cookie making, it did not dramatically increase in height after baking. This was attributed to the cookies made of soft wheat flour which has low gluten content. In addition, cookies containing large amounts of sugar (*i.e.* sucrose) that preferentially attracted water over the gluten proteins did not cause the cookies to rise during baking. Moreover, the type and amount of sugar used can influence the height of cookies (Handa *et al.,* 2012). The height of cookies made of sorbitol (2.90 mm) was significantly ($p < 0.05$) greater than the other cookie samples (2.76, 2.77, and 2.81 mm of Control, CMAL50, and CISO50, respectively), indicating that the cookies expanded at the early stages of baking but did not spread to provide a product of acceptable shape.

Cookie spread is defined as a ratio of diameter to height. Therefore, sugar's influence on the diameter and height are combined into a single parameter (Handa *et al.,* 2012). According to Yamamoto *et al.* (1996), cookies with a larger diameter and higher spread are considered as the desirable quality characteristics. The statistical analysis showed that cookies made of 50% polyols (*i.e.* maltitol, sorbitol, and isomalt) did not affect the spread ratio of the cookies (5.30 - 5.41 mm). Mckemie (2008) reported that the atmospheric pressure could also affect cookie spread. The higher the humidity, the greater the spread of cookies. According to Zoulias *et al.* (2000), the spread of the baked products is controlled by the rate at which the dough flows and by the time at which it stops flowing. The flow rate is associated with the viscosity of the prepared dough. According to Chauhan *et al.* (2016), the viscosity of dough is influenced by the molecular weight of sugars or polyols used. Viscosity decreased as the molecular weight of polyols decreased. Sorbitol has a molecular weight of 182.17 g/mol which is smaller than the other polyols; isomalt and maltitol (344.31 g/mol, respectively) and sucrose (342.30 g/mol) (NCBI, 2018). Therefore, the obtained results of spread ratio in the present work indicated that the sorbitol facilitated the flow of the dough (larger

Table 3. Physical properties of cookies.

Parameter	Control	CMAL50	CSOR50	CISO50
Diameter (mm)	14.72 ± 0.27^{c}	14.82 ± 0.29^{bc}	15.33 ± 0.07^{a}	15.18 ± 0.26^{ab}
Height (mm)	2.76 ± 0.01^{b}	2.77 ± 0.02^{b}	2.90 ± 0.06^{a}	2.81 ± 0.04^{b}
Spread ratio (mm)	5.34 ± 0.10^{a}	5.36 ± 0.12^{a}	5.30 ± 0.12^{a}	5.41 ± 0.11^{a}
Hardness (kg)	3.39 ± 0.23^{a}	3.49 ± 0.47^{a}	2.41 ± 0.13^{b}	2.42 ± 0.16^{b}

Data are means ± standard deviations of three replications ($n = 3$). Means with different superscripts within the same row are significantly different from each other ($p < 0.05$). CMAL50: cookies with 50% maltitol; CSOR50: cookies with 50% sorbitol; and CISO50: cookies with 50% isomalt.

diameter) at the early stages of baking yet set rapidly (high value of height) at the later stages of baking (Table 3).

The replacement of sucrose with maltitol at the level of 50% in cookie preparation (CMAL50) had no significant effect in hardness value with the cookies made of 100% sucrose (Control). However, there was a significant difference ($p < 0.05$) in hardness value between cookies made of 50% sorbitol (CSOR50) and 50% isomalt (CISO50), whereby the control cookies had higher hardness value as indicated by higher mean peak force of 3.39 kg as compared to cookies made of sorbitol (2.41 kg) and isomalt (2.42 kg) (Table 3). These findings are in line with the study by Zoulias *et al.* (2000), whereby cookies made of sucrose replacement by polyols showed softer texture than 100% sucrose cookies. The hardness of cookies involves sucrose recrystallisation and the resulting redistribution of moisture to the other components, which then leads to a firmer texture (Handa *et al.,* 2012) of cookies made of 100% sucrose. In addition, according to Young and O'Sullivan (2011), sorbitol is highly soluble in water that could reduce the crystallisation of sugars in bakery and confectionery products. Therefore, the hardness of cookies can be reduced by reducing sugar crystallisation cookies using polyols.

Colour of cookies

Colour is one of the properties that is firstly perceived by the consumer and affects the acceptability of the baked products. Colour (L^*, a^*, and b^*) of cookies is depicted in Figure 1. CISO50 showed significantly ($p < 0.05$) higher L^* (lightness) value (77.52) than the control cookies (75.10). The results indicated that cookies containing sucrose was darker than the cookies made of polyols, and the colour of the cookies that was dark brown for the control cookies changed into a golden brown colour for the cookies with polyols. This was attributed to the sucrose that acted as a reducing sugar that participated in the Maillard and caramelisation reactions between protein (lysine) and sugars during baking, resulting in a dark colour of bakery products. The colour becomes more intense as the baking temperature increases (Noor Aziah *et al.,* 2012). According to Zoulias *et al.* (2000), the polyols do not participate in Maillard reactions, as they lack a reactive aldehyde group. This is in agreement with the study done by McNutt and Sentko (2003) who had reported that the isomalt is a non-reducing sugar and does not react with amino or peptide groups. Thus, no Maillard reaction occurs during baking. The polyols (*i.e.* sorbitol and isomalt) produced light-coloured cookies, except for maltitol which produced similar brown-coloured cookies as the control (100% sucrose). The results revealed a similar trend to reports from Mushtaq *et al.* (2010). The authors reported that the replacement of polyols for sucrose resulted in a lighter colour on the cookie surface.

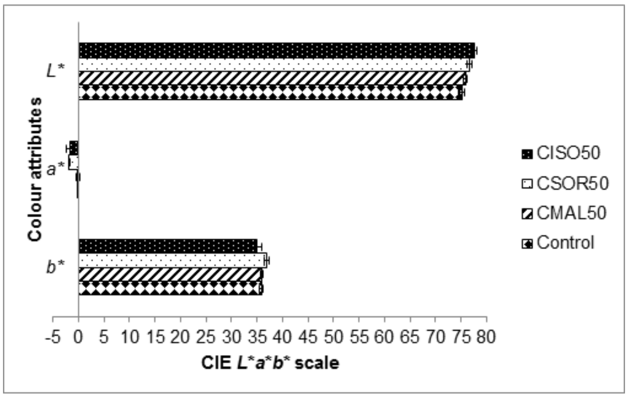

Figure 1. Colour attributes of cookies. Data are means ± standard deviations of three replications ($n = 3$). CMAL50: cookies with 50% maltitol; CSOR50: cookies with 50% sorbitol; and CISO50: cookies with 50% isomalt. CIE $L^*a^*b^*$ scale: Commission Internationale de I 'Eclairage (CIE) $L^*a^*b^*$ scale.

The a^* value correlates with the red or green colours (a positive a^* value is indicative of the red colour; a negative a^* value indicates green colour). The a^* value of all the prepared cookies (with or without polyols) was negative (-0.21, -0.08, -1.80, and -1.56 of Control, CMAL50, CSOR50, and CISO50, respectively), indicating that red hues were not present on the surface of cookies. The a^* value of cookies made of sorbitol (CSOR50) and isomalt (CISO50) was significantly ($p < 0.05$) higher than the cookies containing sucrose (Control) and maltitol (CMAL50). This indicated that the control and CMAL50 presented less greenish colour than the CSOR50 and CISO50. However, no significant differences were recorded for the a^* value in the control and CMAL50 analysed. According to Azmi *et al.* (2016), the colour of cookies can depend on the amount of added sugars present in the dough, which can influence induction of Maillard reactions during the baking process. Some of the important components contributing to the colour include the fats, proteins, and antioxidants, and sometimes the time of baking (Cronin and Preis, 2000). A report from the study by Borrelli *et al.* (2003) indicated that the main components such as proteins and carbohydrates (glucose) were responsible for the browning reactions, thus affecting the sensory attributes of bakery products.

Figure 1 presents an insignificant difference in cookie surface yellowness (a positive b*) values between control cookies (35.88) and cookies made of polyols (35.88, 36.92, and 34.93 of CMAL50, CSOR50, and CISO50, respectively). The *b** value of food is correlated with the presence of phenolic compounds (*i.e.* red, orange, yellow, and blue pigments) and these pigments may or may not affect the organoleptic acceptance by consumers (Oliveira *et al.,* 2014). According to Ho *et al.* (2018), the yellowness value of the baked goods resulted from the pigment colour of the wheat flour. Carotenoid produces (*i.e.* xanthophyll, a free lutein) a strong intensity of yellow pigment present in wheat flour which contributes to a high yellowness value of the wheat-based products. However, the replacement of sorbitol for sucrose resulted in significantly ($p < 0.05$) greater *b** values of cookie surface than the cookies made of isomalt. This was due to the degradation of unstable yellow compounds contained in wheat flour during baking at high temperature.

Sensory evaluation of cookies

The sensory evaluation scores for colour, aroma, mouthfeel, crispiness, and overall acceptability are shown in Figure 2. The cookies made of sorbitol (CSOR50) exhibited lower scores for colour (5.30) than the control (6.00). Colour is an important sensory attribute used to attract the consumer to choose the product. In general, the product colour is influenced by the type of raw material used and preparation method applied. Visual colour reflects the quality of the finished products (Ho *et al.,* 2018). Consumers perceive cookies as either dark or light, and have preferences depending on which type the cookies appears to be. Consumers may reject a light-coloured/pale yellow colour in cookies, which could be easily detectable by the panellists.

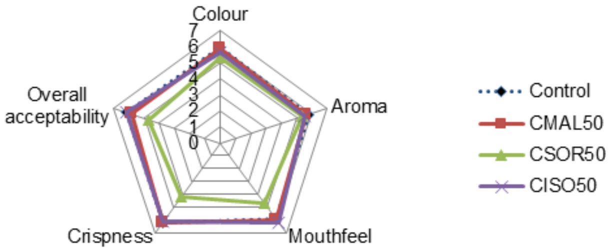

Figure 2. Average score on sensory evaluation of cookies. Data are means ± standard deviations of three replications ($n = 3$). CMAL50: cookies with 50% maltitol; CSOR50: cookies with 50% sorbitol; and CISO50: cookies with 50% isomalt.

In sensory evaluation, aroma attributes are representative of flavour (Azmi *et al.,* 2016). The substitution of maltitol, sorbitol, and isomalt for sucrose at 50% level into the formulations did not affect the aroma of the cookies as compared to the control. The mean sensory scores obtained for the cookies made up of 100% sucrose (Control) and cookies containing polyols (*i.e.* CMAL50, CSOR50, and CISO50) ranging between 5.40 and 5.77. This indicated that panellists were unable to detect the volatile compounds in the cookies that might present very mild aroma. This could be attributed to the polyols that were used, that had no odour, which is similar to sucrose (Deis and Kearsley, 2012). According to Azmi *et al.* (2016), human perception on volatile compounds can differ with that of instrumental analysis.

The results of the sensory analysis revealed that cookies prepared with 50% sorbitol was rated lower by panellists as compared to other cookie samples on mouthfeel attributes. Sorbitol when used as sugar replacers for sucrose, had a lower score (4.67) than the other cookie samples (5.90 - 6.13). This was attributed to the lower fat content of CISO50 than other cookie samples, whereby the CISO50 was recorded to contain 18.51% of crude fat (Table 2). Mouthfeel of food is associated to their fat content. The mouthfeel of a product depends on the way it behaves in the mouth during mastication and is influenced by lubrication (*i.e.* fat droplets). Fat droplets may influence perceived mouthfeel in numerous ways such as alter texture, influence lubrication, and impact coating of oral surfaces (McClements, 2015). The substitution of polyols for sucrose in cookie making results in the decrease of fat droplets in cookies. Therefore, when fat droplets are removed from a food product, the desired mouthfeel attribute is lost.

The perceived crispiness of the cookies with different polyols showed significant ($p < 0.05$) difference between CSOR50 with the other cookie samples. Table 3 presents the hardness value obtained by the peak force and force/deformation value using a texture analyser for cookies made with different polyols and sucrose. The hardness results obtained from sensory evaluation were comparable to the hardness values obtained from instrumental texture analysis. Both panellists and instrument were able to detect the difference between the hardness of the cookies made of 50% sorbitol and control cookies. This was due to the higher moisture content of CSOR50 as opposed to the other cookie samples (Table 2), whereby the wet texture of cookies resulted in soft cookies. Thus, this indicates that the panellists rated a higher preference for harder and crispy cookies. The results of the sensory panel generally agreed with the results of the instrumental measurements of peak force for sorbitol cookies, which were less brittle. Zoulias *et al.* (2000) also reported that the sensory panel preferred cookies with a harder texture.

The mean score for overall acceptance was mostly affected by colour, mouthfeel, and crispiness. Panellists rated the lowest score for sorbitol cookies, which was 'neither like nor dislike' (4.73), while other cookies that were made of maltitol (CMAL50) and isomalt (CISO50) presented no significant difference as compared to cookies made of sucrose. However, all formulations were acceptable by the panellists as they received scores greater than 4, ranging from 4.73 - 6.20. The results of the present work are in close agreement with the findings of Zoulias *et al.* (2000), whereby cookies made of sorbitol received the lowest score for overall acceptability attribute among the prepared cookies.

Conclusion

Maltitol, sorbitol, and isomalt were shown to have a great potential as sugar replacers in producing cookies. These sugar replacers provide numerous functional values to foods including increased crude fibre content, decreased crude fat, and caloric values. All the produced cookies with polyols exhibited significantly lower total sugar than the control cookies (cookies made of 100% sucrose). To this effect, cookies made up of 50% sorbitol (CSOR50) could be claimed as a 'low sugar' cookie product as it contains 4.17% of total sugar which is below 5% as allowed by the Food Act 1983 (Act 281) and Regulations (Laws of Malaysia, 2017), to label it as a 'low-sugar' product. Therefore, CSOR50 would be beneficial for consumers. In addition, sorbitol and isomalt influenced the texture and colour of cookies, making them soft, lighter, and yellowish than other cookie samples. All the produced cookies (with or without polyols) were considered acceptable products as they received an average score higher than 4 (neither like nor dislike).

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