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Sucrose-Free Milk Chocolate Sweetened with Different Bulking Agents: Effects on Physicochemical and Sensory Properties

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ABSTRACT: In the present study, the effects of substituting sucrose with maltitol and xylitol as bulking agents in compound milk chocolate were examined in relation to their physico-chemical, rheological and sensory characteristics. Standard reference chocolate was made using sucrose. The Casson mathematical model was the best fitting model for predicting rheological properties. Compared with chocolate sweetened with sucrose, significant differences in Casson viscosity, yield value and hardness were observed for sucrose-free chocolates. Generally, there was no major difference between chocolate formulations containing high concentration of maltitol and conventional chocolate concerning the following parameters: moisture content, mean particle size and sensory properties. However, sucrose replacement with the high ratios of xylitol had higher moisture content, greater Casson viscosity and an increased flow behaviour index. These findings illustrate that it is possible to manufacture chocolate using high concentration of maltitol without affecting its important physico-chemical characteristics and sensory attributes.

Key words: Chocolate, maltitol, rheology, sensory characteristic, xylitol

INTRODUCTION

In recent years, sugar-free chocolates have been developed for those people who suffer from obesity and diabetes, because they have reduced calorie values, glycemic index and also prevent dental cavities (Olinger, 1994). One way of making chocolate with reduced calorie is to replace sucrose with bulking agents such as sugar alcohols. Bulk sweetener substituted for sucrose in chocolate should provide sweetness, stability and mouthfeel (texture) for an acceptable product (Jeffery, 1993).

Crystalline maltitol is a disaccharide polyhydric, produced by catalytic hydrogenation of maltose which consists of glucosyl-sorbibtol units (Nabors, 2001). It has a sweetness of almost 85-95% that of sucrose. The cooling effect of maltitol is close to that of sucrose (-23 kJ/kg). Maltitol's anhydrous crystalline form is non-cariogenic, thermo stable and substantially non-hygroscopic. In humans, maltitol causes no significant increases in blood glucose and insulin level. It has an energy value of approximately 2.4 Kcal/g and that no more than 40% is hydrolyzed in the small intestine (Beaugerie *et al.,* 1991). D-Maltitol is an excellent substitute for sucrose in non-sugar chocolate, because it provides similar texture and taste to that of sucrose and also it is suitable for diabetics. As a whole, maltitol is the only sugar alcohol, which presents the most similar organoleptic and technological properties to sucrose (Mitchell, 2006).

Xylitol as a commercial available preparation is produced by the chemical conversion of xylan. It has a very similar sweetness profile to sucrose, and the only polyol that is needless of any additional intense sweetener. Xylitol exhibits a pleasant cooling effect in the mouth, because it absorbs energy from the environment as it dissolves, however the strong cooling effect of xylitol can be moderated by adding other bulk sweeteners with low heat solution value such as maltitol. In the small intestine, 25-50% of ingested xylitol is absorbed. The rest of the sugar alcohol becomes a substrate for bacterial fermentation in large intestine. After ingestion of xylitol, the plasma glucose and insulin level are significantly lower than sucrose and this means that it can be used as a suitable sweetener in diabetic diets, because conversion of xylitol to glucose occurs very slowly in liver, thus does not impart in major increase in blood glucose. Xylitol has caloric value of 2.4 kcal/g (Mitchell, 2006).

Presently there are some studies about the sugar-free chocolates made with maltitol and xylitol. Sokmen and Gunes (2006) used maltitol, xylitol and isomalt in the formulation of dark chocolate and finalized that chocolates made with maltitol resulted in similar rheological properties in compared to sucrose.

Konar (2013) evaluated the influence of maltitol and inulin as bulking agents in milk chocolate and stated that samples undergo significant changes with varying conching temperature. Although many different studied have been carried out about the influences of different bulking agents on quality parameters of free-sugar chocolates, but the effects of bulking agents such as maltitol and xylitol on compound milk chocolate properties still remain unclear. Therefore this is the first study on maltitol and xylitol's effects on the quality parameters of the compound milk chocolate.

The main aim of this study was to produce sucrose-free sweet chocolates. Therefore, sugar alcohols (maltitol and xylitol) were used as ingredients for the production of chocolates. The formulated samples were evaluated for their important physical properties (moisture content, mean particle size, hardness), rheological characteristics, sensory attributes and acceptability among panelists.

MATERIALS AND METHODS

A. Materials

The ingredients including cocoa powder (Altinmarka, Turkey), lauric cacao butter substitute CBS (MOI Malaysia), whole milk powder (Zarrin-shad, Iran), maltitol and xylitol (Roquette Frères, France), sucrose (Iran sugar Co., Iran), soy lecithin (Cargill, Netherlands) and vanilla powder (Polar Bear, China) were used for the production of milk chocolates.

B. Chocolate manufacturing

In the current study, the chocolate mass (six batches) was made in the laboratory ball mill (home-built, Tabriz university) with a capacity of 5 Kg. The diameter of balls in the mill was 8 mm. Homogenization was carried out at 55°C at an agitator shaft speed of 40 rpm, recycling the mass through the balls at a medium speed of 10 Kg/h of the recycling pump, for 4-5 hour. All the ingredients were added to the ball mill at the beginning of the production period. Refined compound milk chocolate was molded and cooled at 5°C for 30 minutes, removed from the moulds, wrapped in aluminum foil and stored at 18°C. The control samples contained sucrose instead of sugar substitutes. Table 1 presents the formulation used in chocolate production and the batches of chocolates which underwent quality analysis.

Table 1: Formulations used for the chocolate samples (% w/w).

	Ingredients (%)							
Treatment	**Cocoa powder**	**CBS**	**Sucrose**	**Lecithin**	**Vanillin**	**Maltitol**	**Xylitol**	**Whole milk powder**
T_1	6	34.5	-	0.5	0.01	33	-	26
T_2	6	34.5	-	0.5	0.01	-	33	26
T_3	6	34.5	-	0.5	0.01	16.5	16.5	26
T_4	6	34.5	-	0.5	0.01	24.75	8.25	26
T_5	6	34.5	-	0.5	0.01	8.25	24.75	26
Control	6	34.5	33	0.5	0.01	-	-	26

C. Moisture content

The moisture content of chocolate samples was measured by an official standard gravimetric method (AOAC, 1990).

D. Particle size determination

After refining, the particle size of all chocolate samples was measured by a micrometer produced by Mitutoyo (Tokyo, Japan). Approximately 2 gr of chocolate at 45°C was dispersed in white mineral oil before being placed in an optical micrometer and a mean particle size was measured. Measurements were replicated 5 times (Lucisano *et al.,* 2006).

E. Rheological assessment of molten chocolate

The flow behaviour of the melted chocolate samples was evaluated using a shear-rate/shear stress controlled rheometer (Anton Paar, MCR301, Austria). The measurements were carried out at 40°C using a coaxial cylinder system (cup and bob) and applying a shear rate varying from 5-50 s^{-1}. Each measurement took 180 s at 40°C and 50 measurements were taken (Afoakwa *et al.,* 2009). Collected data were fitted with mathematical models including Power law (Eq. 1), Bingham (Eq. 2), Herschel-Bulkley (Eq. 3) and Casson (Eq. 4) (Abbasi and Farzanmehr, 2009).

$$\sigma = \kappa\gamma^{n} \quad (1)$$

$$\sigma = \mu_{pl}(\gamma) + \sigma_0 \quad (2)$$

$$\sigma = \kappa\gamma^{n} + \sigma_0 \quad (3)$$

$$(\sigma)^{0.5} = (\kappa_1)^{0.5}(\gamma)^{0.5} + (\sigma_0)^{0.5} \quad (4)$$

[σ represents shear stress (Pa); κ, consistency coefficient $(Pa.s)^n$; γ, shear rate (s^{-1}); μ_{pl}, plastic viscosity (Pa.s); σ_0, yield stress (Pa); κ_1, Casson plastic viscosity (Pa.s); *n*, flow behaviour index (dimensionless)].

The best fitted model was selected by two statistical indexes of Root Mean Square Error (RMSE) and coefficient of determination (r^2) (Yeganehzad *et al.,* 2013).

The rheological parameters including plastic viscosity and yield stress values of the selected models were determined.

F. Mechanical properties

The hardness of solid chocolate was evaluated using TA. XTplus- Texture Analyser with a penetration probe (needle P/2) and a 50 Kg load cell. Hardness was reported as the maximum penetrating force (N) required for the needle to penetrate through a sample (80 × 20 mm, depth 8 mm) at 20°C over a distance of 5 mm at a constant speed of 2 mm/s. Mean values from 4 replicate measurements and standard deviations were calculated (Afoakwa *et al.,* 2008).

G. Sensory evaluation

Sensory attributes of milk chocolates including appearance (form, colour, brightness, surface), texture (structure, break, firmness), chewiness, aroma, odor, taste and overall acceptability were evaluated using a hedonic scale test (5-point eating test, 1= detective product, 2= dislike, 3= tolerable quality, 4= desired quality, 5= extremely desired quality) based on a balanced incomplete block design by 15 trained panelists. Chocolates were identified with a different three-digit code. Panelists consumed water and crackers between assessments (Popov-Raljic and Lalicic-Petronijevic, 2009; Belscak-Cvitanovic *et al.,* 2015).

H. Statistical analysis

Quantitative data was expressed as mean values of 3 replicates. Statistical analysis was performed using Minitab 16 and the level of significance was preset at $P<0.05$. The results were analysed using the Tukey's test. MATLAB software (v. R2012a) was used for the four rheological models.

RESULTS AND DISCUSSION

The effects of various combinations of sugar alcohols on the mean values of moisture content, particle size, Casson plastic viscosity, Casson yield stress, flow index and hardness are shown in Table 2. For comparison aims, experiment 6 represents the control formulation made with sucrose.

A. Moisture content

Mean values for the moisture content were analysed (Table 2). Column charts demonstrating the effect of the ingredients on the moisture content is shown in Fig. 1. As it can be seen, there are significant differences ($P<0.05$) between the moisture content of some samples and control, but the lowest value belonged to formulations containing 100% maltitol. In contrast, formulation containing high mass fractions of xylitol had the highest moisture content (Table 2). Generally, the high moisture content of formulations can be ascribed to high and low hygroscopicity of sugar alcohols (i.e. xylitol) and maltitol, respectively. Chocolate formulations containing high ratios of maltitol were not different from control in term of moisture content (Fig. 1).

Table 2: Physico-chemical analysis of chocolate samples prepared with bulking agents.

Sample	Moisture (%)	Mean particle size (μm)	Casson viscosity (Pa.s)	Yield stress (Pa)	Flow index	Hardness (N)
T_1	0.88±0.014	27.7±0.548	1.62±0.021	4.14±0.003	0.72±0.007	6.75±0.014
T_2	1.17±0.021	35.5±0.548	2.65±0.003	1.84±0.002	0.84±0.007	4.81±0.028
T_3	1.05±0.007	31.5±0.548	2.33±0.002	2.72±0.003	0.81±0.007	5.5±0.035
T_4	0.98±0.007	29.7±0.447	2.01±0.001	3.37±0.002	0.76±0.007	6.08±0.049
T_5	1.09±0.004	33.5±0.548	2.54±0.002	2.22±0.001	0.82±0.007	5.07±0.021
Control	0.92±0.007	27.3±0.447	1.72±0.012	3.82±0.035	0.75±0.007	6.43±0.028

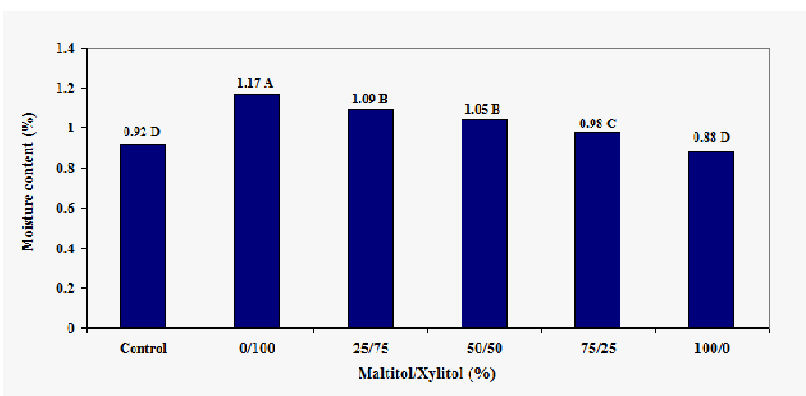

Fig. 1. Effect of sugar substitutes concentration on moisture content of chocolate.

The moisture content for the samples ranged from 0.88% to 1.17% which was within the acceptable limit (<1.5%). A general trend emerged that, decrease in maltitol concentration with simultaneous increase in xylitol concentration led to increase in moisture content. The latter could be due to high water-holding capacity of xylitol. Xylitol possesses hydroxyl groups on its chemical formula which is the cause of increasing and preserving of the moisture in formulations with high content of xylitol. It can absorb some moisture that is released from ingredients such as milk powder during conching.

In a previous study, chocolate formulations possessing high proportions of maltodextrin, inulin and polydextrose indicated higher moisture content (Farzanmehr and Abbasi, 2009). The findings revealed the higher hygroscopicity of the above ingredients. Aidoo *et al.* (2014) also reported higher moisture content for chocolate formulations containing high levels of sugar substitutes.

B. Mean particle size of the samples

The effects of various combinations of sucrose substitutes on the mean particle size are shown in Table 2. The results in Table 2 show that the mean particle size of all chocolate formulations ranged from 27.3 to 35.5 with control samples having the smallest and xylitol formulations having the largest size. The mean particle size of the 100% xylitol chocolate was significantly greater (P<0.05) from maltitol formulations while 100% maltitol samples were very similar (P<0.05) to control (Fig. 2).

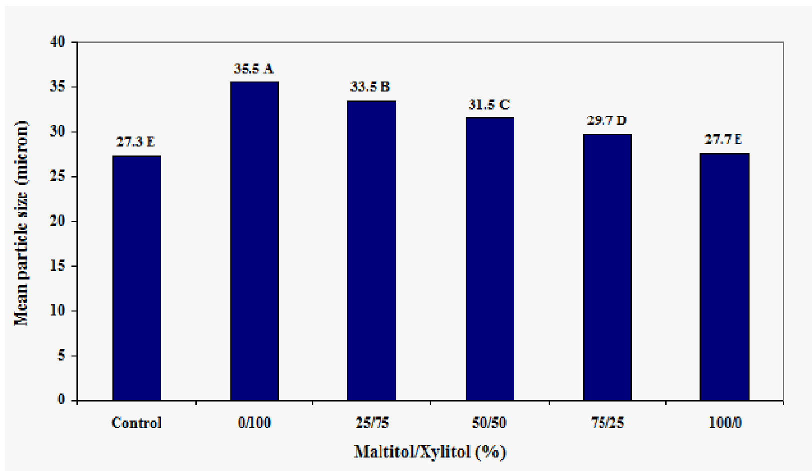

Fig. 2. Effect of sugar substitutes concentration on mean particle size of chocolate.

Hygroscopic sugar alcohol such as xylitol absorbs moisture during chocolate production resulting in particles agglomeration. Chocolate with high degree of agglomeration due to a higher moisture level will not exhibit higher reduction in particle size.

Chocolate texture and flow properties are mainly influenced by particle size distribution (Minifie, 1989). Particles with smaller sizes basically affect the rheological properties of chocolate, but the biggest ones are important for mouthfeel and have an impact on the coarseness. Awua (2002) noted that optimum particle size for dark chocolate is achieved at mean sizes lower than <35 however, the amount is influenced by product and ingredients composition. Chocolate with particle size above 30 has a gritty or coarse perception in the mouth (Afoakwa *et al.,* 2008). Moreover, Servais *et al.* (2002) reported that particles larger than 35 causes chocolate to become gritty which results in lower acceptance. All samples in this study except formulations containing 100% xylitol had a mean particle size less than 35 denoting that no grittiness should be perceived during consumption.

In a study by Sokmen and Gunes (2006) it was shown that chocolate samples containing maltitol contained a higher amount of smaller particles in comparison with isomalt and xylitol formulations. Also Gomes *et al.* (2007) investigated the application of various bulk agents such as lactitol and maltitol in chocolate production. In their research, the particle size varied from 19 to 21 which was in acceptable limit (<30).

C. Rheological analysis of chocolate samples

Statistical evaluation of the models indicated that the Casson model was the best at describing the rheological behaviour of chocolate samples. On the other hand, IOCCC have offered the Casson model to describe the flow behaviour of the chocolate (Bouzas and Brown, 1995). Result illustrated that replacing sucrose with maltitol and xylitol, in spite of influencing the rheological properties, had no effect on the mathematical model fitting and the same model being able to be used for the determining of flow behaviour of all the chocolate samples.

C_1: Casson plastic viscosity

The results demonstrated that there are significant differences ($P<0.05$) between the Casson viscosity of sugar-free chocolates and control (Fig. 3). In our study, chocolate with xylitol exhibited higher viscosity than did the control. But the plastic viscosity of chocolate containing maltitol was lower than the control (Table 2). Casson viscosity values ranged between 1.62 and 2.65 Pa.s (Table 2), which is in a very good agreement with the data reported by Toker *et al*. (2016) for compound milk chocolate (1.83-2.31 Pa.s). This means these sugar alcohols can be easily applied for compound milk chocolate production.

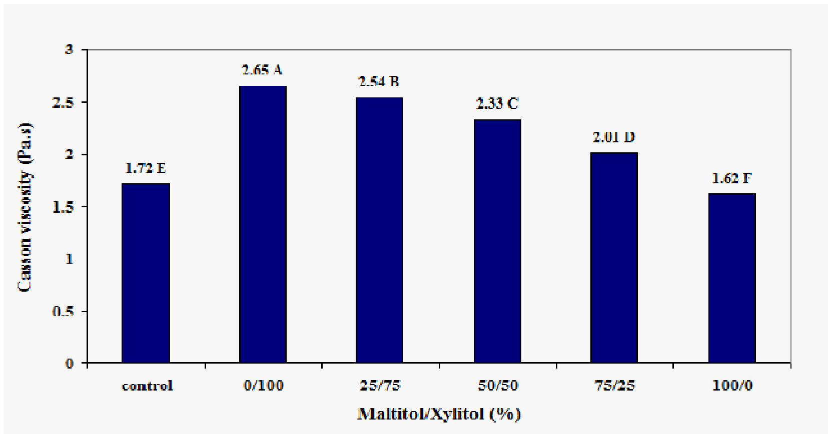

Fig. 3. Effect of sugar substitutes concentration on Casson viscosity of chocolate.

The results show that Casson viscosity of the treatments was influenced by particle size and moisture content of the chocolates. Chocolate containing 100% xylitol (T_2) which exhibited the highest moisture content and greater mean particle size had the highest Casson viscosity. Conversely, T_1 with relatively low moisture content and less mean particle size exhibited the lowest Casson viscosity.

Free moisture within the matrix of chocolate causes the sugar particles dissolve and stick together thus results an increase in viscosity (Saputro *et al.,* 2016). Xylitol is very hygroscopic, which will absorb water from the environment (moisture released from milk powder). Ziegleder *et al.* (2004) reported that, increasing the moisture content of the chocolate leads to an increase in chocolate viscosity. Also, in the study of Abbasi and Farzanmehr (2009) chocolate samples containing high levels of sugar substitutes (100% maltodextrin) had higher moisture content and Casson viscosity.

On the other hand, rheological properties of chocolate are basically influenced by particle size distribution (Aidoo *et al.,* 2013). Fat is partially tied to the particle surfaces. Particles with smaller size have more surface area; therefore as particles get smaller, more fat will coat the particles hence decrease the viscosity. According to Bouzas and Brown (1995), chocolate with smaller particles size will result in the lowest plastic viscosity.

C_2: Casson yield stress

Casson yield values for milk chocolate have been reported to be between 2-18 Pa (Aeschlimann and Beckett, 2000). Nearly, 80% of the yield stress values as estimated by the Casson model for the samples in our work were within the range reported (Table 2). Generally, increasing in maltitol concentrations with simultaneous reduction in xylitol concentration resulted in substantial increase ($P<0.05$) in the Casson yield value. The highest Casson yield was achieved by substituting sucrose entirely with maltitol. In opposite, milk chocolates formulations with high amounts of xylitol (100%) resulted in the lowest Casson yield. Chocolate containing the highest maltitol was found to be close to control in tested Casson yield value (Fig. 4).

Yield stress is defined as the amount of energy required to initiate motion in molten chocolate and determined by particle-particle interaction, the amount of specific surface area, emulsifiers and moisture. Particle size distribution and ingredients used in chocolate manufacturing are the two main factors influencing chocolate rheology properties (Aidoo *et al.,* 2013). Also, Beckett (2000) noted that mean particle size and specific surface area of particles influence yield stress. This means that smaller particle sizes increase the surface area of the dispersed particles and thus, the stronger the particle-particle interactions will be, resulting in higher yield numbers. Moreover, Prasad *et al.* (2003) concluded that, yield stress is dependent on mean particle size and specific surface area. This explains the high yield values for maltitol formulations.

In the study of Sokmen and Gunes (2006) chocolate samples containing maltitol had higher yield stress in comparison to isomalt and xylitol due to maltitol's PSD, which contained more amounts of smaller particles.

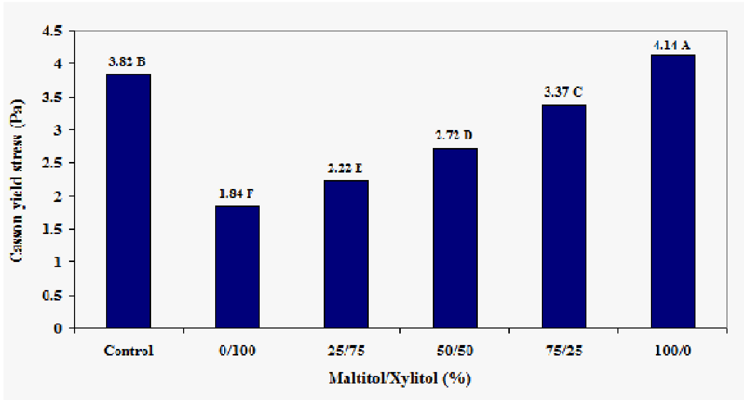

Fig. 4. Effect of sugar substitutes concentration on Casson yield of chocolate.

As the particle size increased, the yield value of samples decreased significantly. Low yield values in the formulations containing high concentration of xylitol demonstrates that interaction forces between xylitol particles were weak and thus, less force is needed for flow of the formulated chocolates.

On the other hand, the high yield value for samples containing 100% maltitol can be attributed to high molecular mass of the ingredient (Abbasi and Farzanmehr, 2009). It can be pointed out that high Casson yield number of maltitol samples is due to agglomeration mechanism in suspension systems. High molecular weight of maltitol increases the intermolecular (non-polar) interactions in chocolate mass. As a result the mass becomes firmer and agglomerates and thus, more energy is required to start flowing. Therefore, higher yield value of chocolate with maltitol could be associated with the high molecular mass of maltitol (344) vs. xylitol (152).

C_3: Flow index (n).

Flow behaviour index of all chocolate samples ranged from 0.72 to 0.84 (Table 2). There were significant differences ($P<0.05$) between some samples (Fig. 5). Value of all chocolate formulations lower than 1 indicated slight shear thinning behaviour above yield stress. As a whole, sucrose replacement with xylitol resulted in higher flow index ($P<0.05$).

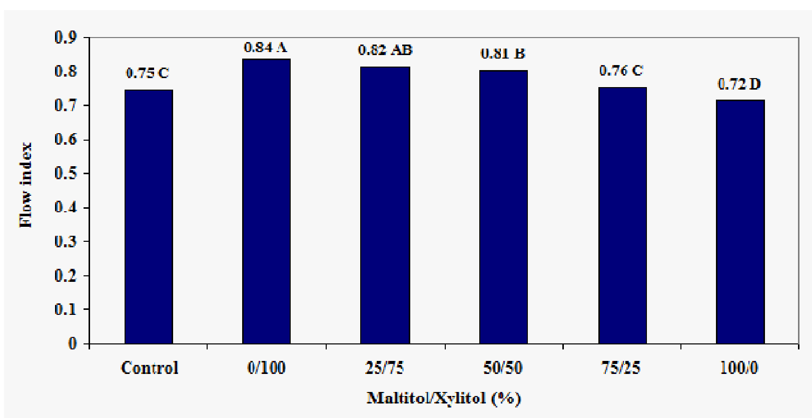

Fig. 5. Effect of sugar substitutes concentration on flow index of chocolate.

This outcome may be a result of the higher crystanillity of xylitol in comparison with maltitol. Xylitol has a severe tendency for crystallization. In a suspension system like chocolate, xylitol molecules have inclination to aggregate together and form crystal, resulting in increase in flow index.

Flow index could be correlated to strengths of the aggregated particle-to-particle network system of chocolate blend during manufacture (Servais *et al.*, 2004; Beckett, 2000). Afoakwa *et al.* (2007) noted that several factors including distribution and arrangement of particles, fat and emulsifier contents influence the rheological flow behaviour of chocolate. The rate index of dark chocolates containing xylitol produced by Sokmen and Gunes (2006) had higher value than chocolates containing maltitol and isomalt. The results indicated that almost all the samples containing isomalt and maltitol, were pseudoplastic ($0<n<1$).

D. Hardness

The hardness of the chocolates varied significantly (P<0.05) among the samples ranging from 4.81 N to 6.75 N (Table 2). Formulations containing high levels of xylitol recorded the least hardness value with a combined average of 4.81 N. Overall, samples containing 100% maltitol was the hardest with a combined average of 6.75 N compared to the control (6.43 N).

This can be attributed to differences in the particle density, mean particle size, moisture level and sugar composition of sweeteners. Hardness showed an inverse relationship with the mean particle size with significant reductions (P<0.05) at all samples containing xylitol, but greatest at 100% xylitol treatments (Fig. 6). Greater hardness with 100% maltitol and 27.7 *μm* mean particle size suggest more particle-particle interactions.

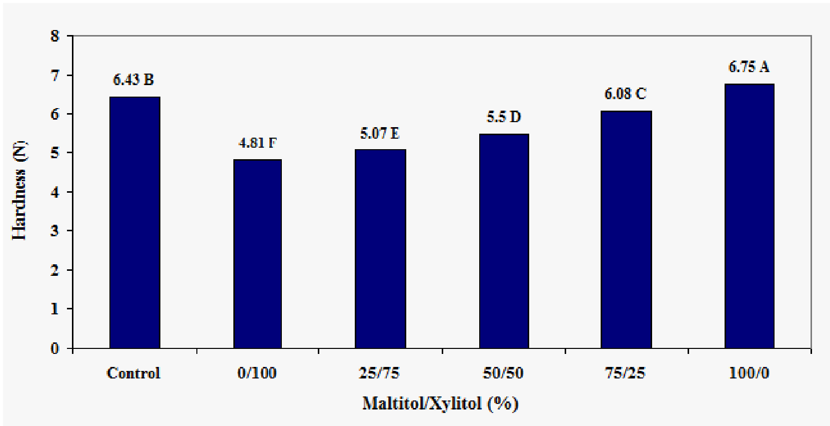

Fig. 6. Effect of sugar substitutes concentration on hardness of chocolate.

The final hardness of solid tempered chocolate is correlated with the type of fat and its content, particle volume fraction, particle size distribution, the type of sugar and the tempering process (Afoakwa *et al.*, 2008; Beckett, 1999). Beckett (1999) stated that largest particle size determines chocolate coarseness and textural properties. In the study of Afoakwa *et al.* (2008) increasing particle size from 18 to 50 caused significant reductions in firmness and consistency. Chocolates with smaller particles have larger specific surface areas, lower mean particle size and more interactions between particles than chocolates with coarser particles; yielding in higher firmness.

Do *et al*, (2007) reported that reduced hardness can be achieved in samples having low contact levels between particles in suspension. Replacement of maltitol as bulking agent in the study of Konar (2013) had no substantial effect on chocolate hardness.

E. Sensory acceptability of formulated chocolates

Among the chocolates produced in this research, control chocolate was scored the best in terms of all sensory attributes (Fig. 7). The appearance score of all samples in this study ranged from 4.63 to 4.93 with no significant (P<0.05) differences between samples. Sucrose replacement with sugar alcohols had no substantial effects (P<0.05) on chocolate hardness and mouthfeel (Fig. 7). Aroma is another sensory property and appears as one of the most important attributes. The control sample perceived as the most liked (4.66) followed by samples containing 100% maltitol (4.56). Reduction of maltitol concentration resulted in apparent low (P<0.05) aroma acceptance. Aroma, taste and odor of chocolate made of 100% maltitol were the most similar to control chocolate. Generally, it can be observed that conventional chocolate was preferred by the panelists over all sugar-free types regarding their flavour attributes. Flavour properties of samples exhibited more substantial (P<0.05) differences depending on concentration of sugar-alcohol used in manufacturing the chocolate.

Totally, the overall acceptability ranking was in accordance with the ranking of aroma, taste and odor, indicating that these properties contribute the most preferences of the consumers. According to that, chocolate containing 100% maltitol and control characterised with the highest overall acceptance and chocolate made of 100% xylitol, exhibited the lowest acceptability.

Different ingredients proportions, cocoa types, variations in processing techniques and particle size distribution will result in different sensory properties (Jackson, 1999). Beckett (2000) noted that the largest particles are important for mouthfeel with respect to grittiness. Smaller particles in chocolate could improve the sensory characteristics (Ziegler *et al.,* 2001).

Unique and complex aroma of the chocolate is one of the most important properties that have made it popular among the consumers (Owusu, 2010). Different cocoa genotype, degree of fermentation, drying, recipe, mean particle size, fat type and processing conditions affects the aroma and the release of the volatile compounds of chocolate (Saputro *et al.,* 2016; Toker *et al.*, 2016).

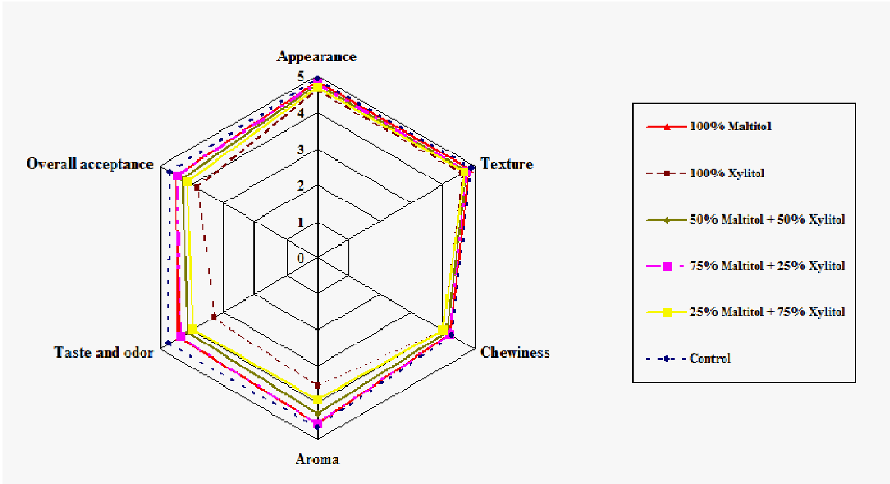

Fig. 7. Spider chart representing sensory attributes of formulated chocolates.

Decreasing particle size with increase in surface area would facilitate the volatile compounds release from the chocolate matrix (Afoakwa, 2010). The findings of the present study confirmed the effect of particle size on the aroma attributes of the samples. Toker *et al.* (2016) studied the particle size on volatile compound profile of compound chocolate and found that direct relationship was observed between particle size and some flavour compounds concentrations such as pyrazines.

When maltitol is added to chocolate the sensory quality of the product will not be affected strongly due to its neutral or slightly sweet taste and its limited effect on viscosity. The results of this study indicate the potential of using sugar alcohols to completely replace sucrose and achieve the desired sensory characteristics.

CONCLUSION

A sucrose-free compound milk chocolate with maltitol and xylitol as bulking agents was successfully developed. Substitution of sucrose by maltitol and xylitol blends has varied influences on the rheological properties and physical quality. The effect was dependent not only on the type of sugar alcohol used but also on the concentrations present. Sugar replacement with high mass fractions of xylitol yielded in different physico-chemical and sensory properties in comparison to reference chocolate. High mean particle size and high moisture content of the samples made with xylitol were the main reasons for the higher viscosity, lower sensory scores and hardness of the resulting chocolates. Although the values almost fell in the standard ranges reported for the chocolate. However, it is possible to reduce the magnitude of the changes induced by a decrease in the ratio of xylitol.

A very interesting relationship between particle size of sugar alcohols and some parameters (Casson viscosity, yield stress, hardness and sensory properties) was observed. Generally, maltiol addition to sugar-free chocolate formulations had no major effects on moisture content, mean particle size and sensory attributes as compared to the reference chocolate containing 33% sucrose. The sensory results obtained in this research have shown that on an overall basis, new product-sugar-free chocolate was accepted quite well among panelists of different ages. Maltitol can be recommended as a suitable sucrose replacement in chocolate recipe. The findings of this study indicated that the sucrose substitution by bulking agents have potential as a pleasant food in the formulation of diabetic/reduced calorie milk chocolates. Future experiments will focus on the optimization of the formulation of free-sucrose compound milk chocolate based on physicochemical and sensory properties.

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