J. Agr. Sci. Tech. (2016) Vol. 18: 643-656

Effects of Sucrose Substitution with Date Syrup and Date Liquid Sugar on the Physicochemical Properties of Dough and Biscuits

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ABSTRACT

To reduce sucrose consumption in biscuits, Date Syrup (DS) and Date Liquid Sugar (DLS) were replaced with sucrose at different levels (0, 20, 40, 60, 80, and 100%) and physicochemical properties of dough and the resultant biscuits were compared. Dough pH and cohesiveness decreased while softness and adhesiveness increased with addition of DS and DLS. The pH, softness and adhesiveness of the DS dough were higher than the DLS samples. The DS and DLS biscuits had lower pH, higher ash and moisture contents than the sucrose biscuits. The DS biscuits had more ash content than the DLS sample. Addition of DS and DLS resulted in biscuits with higher density, spread ratio, harder texture, and darker color. These changes were more pronounced when DS was used. Sucrose replacement with less than 40% DS or 60% DLS resulted in biscuits with sensory characteristics similar to the control, and higher antioxidant and mineral contents.

Keywords: Antioxidants, Mineral contents, Sensory characteristics, Sucrose reduction.

[DOR: 20.1001.1.16807073.2016.18.3.11.3]

INTRODUCTION

Sugar is an essential ingredient in many foods including bakery products such as cakes and biscuits. In such products, sugar provides sweetness, contributes to the texture, flavor, and color. Sugar characteristics including type, amount, and particle size affect the quality of the product mainly by influencing the amount of soluble sugar, gluten network formation, and starch gelatinization (Manley, 2011; Parey *et al*., 2008).

Sugar beet and sugarcane are the main sources of sugar (sucrose) worldwide. However, due to the high consumption of sucrose, seeking alternative sources is necessary. By now, sugar from carob, glucose syrup from local starch sources such as palm and cassava, fructose from cashew apple juice and cereal stems, date fruit and its products, inulin and polydextrose, arabinoxylan oligosaccharides, and other sources have been used to reduce sucrose consumption (Olinger and Velas, 1996; D'Egidio *et al*., 1998; Azevedo and Rodrigues, 2000; Sidhu *et al*., 2003; Mariotti and Alamprese, 2012; Aidoo *et al*., 2014).

Dates fruits contain high amount of sugar (44-88%) and have been used as a source of sugar in many food products. Two common products with high sugar content are obtained from date fruit including Date Syrup (DS) and Date Liquid Sugar (DLS). They are economical products since they are produced from low quality dates suitable for human consumption and are considered as natural sources of liquid sugars (Ashraf Jahani, 2002; Al-Farsi *et al*., 2008).

DS, which is also named "Rub" or "Dibs", leaks out naturally by the force of date fruits weight when bagged Fresh dates are piled for a long time. Home-made and industrial DS are

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produced in many countries. The general method for industrial DS production involves crushing of date fruits by means of special rollers, soaking in water after pretreatments for better penetration of water into the dates, juice extraction, filtration, and concentration (Ashraf and Hamidi-Esfahani, 2011). Besides high amount of sugars, DS contains carbohydrates, proteins, lipids, pectin, minerals, vitamins, and salts. It also contains potent antioxidant and strong free radical scavengers and has antimutagenic activity (Ashraf Jahani, 2002; Mansouri *et al*., 2005; Alanazi, 2010). It has been shown that the inclusion of DS in pan bread and cookies boosted the nutritional value of the products by increasing the levels of minerals and vitamins (Almana and Mahmoud, 1991; Sidhu *et al*., 2003; Ahmadi *et al*., 2011).

Removing all materials except glucose, fructose, and sucrose from refined DS results in another date product called Date Liquid Sugar (DLS) with soluble solid content of about 75%. Regarding the high sugar content and hence sweet taste, availability in many parts of the world and health benefits of the DLS and DS, it is feasible to use them instead of sucrose in different foods. Accordingly, DS and DLS have found applications in soft drinks, jellies, ice cream, canned fruits, cookies, cakes, and pan breads (Almana and Mahmoud, 1991; Ashraf Jahani, 2002; Ahmadi *et al*., 2011; Ashraf and Hamidi-Esfahani, 2011). However, some unwanted effects, mainly including increased darkness and loss of consumer acceptability, have been reported when sucrose was replaced with date products. For instance, DS was used in chocolate-flavored layer cakes at 0, 25, 50, 75, and 100% replacement levels. Although the quality of the cakes decreased after sucrose substitution, chocolate cakes containing 25% DS remained similar to the sucrose control in all aspects, except for color (Almana and Mahmoud, 1991). Although the number of commercial products containing DS and DLS is growing, there is a lack of knowledge about their effects on biscuit quality, particularly by comparing their impacts on dough and the resulting biscuits.

The main objective of this study was to reduce the amount of sucrose consumption in biscuit by substitution of sucrose with DLS and DS which are rich in minerals and antioxidants. Thus, the product would be healthier. In addition, the aim was to determine the effects of sucrose replacement on physicochemical properties of dough and biscuits and to compare the most appropriate levels of DS and DLS in the biscuit recipe.

MATERIALS AND METHODS

Soft wheat flour with extraction rate of 72%, shortening, glucose syrup, sodium bicarbonate, sodium pyrophosphate, lecithin, wheat starch and sodium chloride were supplied by Tina biscuit manufacturing company, Marvdasht, Fars province, Iran, The flour contained 11.8% moisture, 10.5% protein, 1.1% ash, 18.4% wet gluten and 6.1% dry gluten as determined by the Approved Methods of the AACC (2000), methods 44-15.02, 46-13.01, 08-01.01, 38-12.02, respectively. Sucrose in the form of white fine sugar extracted from sugar beet and fresh whole eggs were purchased locally. DS and DLS were produced by a fully automated production line and gifted by Ghand-e-Khorma Minoo Company, Shiraz, Iran. Chemicals required for analytical tests were purchased from Merck, Germany.

Determination of the Chemical Characteristics of DS and DLS

Glucose and fructose content of DLS and DS were determined using High Performance Liquid Chromatography (HPLC) (Agilent 1200, Germany) according to the Approved Methods of the AACC (2000), method 80-04.01. Protein content, total soluble solids and pH were measured using AACC (2000) methods 46-13.01, 80-51.01 and 02-52.01, respectively. The amounts of Cu, Fe, Na, P, Mg, Mn and Zn were measured by using atomic absorption spectrometer (Shimadzu, AA-650G, Tokyo, Japan) according to the AOAC (2000) Method 03/975. Flavonoid content was determined using the aluminum chloride colorimetric method as described by Van Hung *et al*. (2009) and total phenolic compounds were measured calorimetrically using Folin-Ciocateau reagent as described by Velioglu *et al*. (1998) with slight modifications. The 2, 2-DiPhenyl-1-PicrylHydrazyl (DPPH) radical scavenging capacity of the DS and DLS was determined by the method illustrated by Van Hung *et al*. (2009).

Biscuit Dough Preparation

Biscuit dough was prepared according to the following recipe: 100 g flour, 28 g shortening, 28 g sucrose, 19 g water (accounted for the water content of the DS or DLS), 4.7 g whole egg, 3.2 g wheat starch, 0.37 g sodium chloride, 0.45 g sodium bicarbonate, 0.45 g sodium pyrophosphate, 0.45 g lecithin and 3.6 g glucose syrup, which were accurately weighed. Sucrose was substituted with DS or DLS at levels of 0, 20, 40, 60, 80 and 100% (w/w, dry weight, sucrose basis) in the dough recipe, separately.

To make biscuit dough, shortening and sucrose were creamed thoroughly using a kitchen mixer (Kitchen–Moulinex mixer, Model HM1010, Beijing, China) at 61 revolution per minute (rpm) for 2 minutes and then all ingredients, except starch and flour, were added and mixed well for 12 minutes. Wheat starch and flour were then added gradually to the creamy mixture and mixed at 125 rpm for 2 minutes to a homogenous mass using a dough mixer (Kenwood, KM330 Bench Mixer, China). The moisture and pH of the dough were determined according to the AACC (2000), methods 44-15.02 and 02-52.01, respectively.

Evaluation of Textural Properties of Biscuit Dough

Shortly after dough production and before sheeting and moulding, a cubic piece of dough was prepared with dimensions of 2.5×2.5×0.7 cm using a metallic mould with sharp edges. Textural properties of the dough were determined using a TA-XT2 texture analyzer (Stable Microsystems Ltd, Surrey, UK) provided with the Texture Expert software. A metallic cylindrical probe with diameter of 80 mm was used in a Texture Profile Analysis (TPA) double compression test. The compression was continued down to 25% of the initial height of the sample, at pretest speed of 5 mm s^{-1}, test speed of 0.25 mm s^{-1}, with a 10 seconds delay between first and second compressions. The test was carried out on six individual samples and the mean value was recorded. Parameters obtained were firmness, cohesiveness, and adhesiveness, which were calculated from the resulting curves (Bourne, 2002).

Biscuit Production

The dough was placed on a non-sticky surface and rolled out with a rolling pin to a thickness of 7 mm, then moulded by a stainless steel mould to a final dimension of 48×36×8 mm. The moulded dough were placed on a Teflon baking tray and after 30 minutes of rest, baked at 180°C in an electrical oven (Nan-e-Razavi Company, Iran) for 20 minutes. After cooling at ambient temperature, the biscuits were packed in high density polyethylene bags and stored at 25°C for further experiments.

Evaluation of Biscuit Properties

Chemical Properties

The moisture and ash contents and pH of the biscuits were measured according to the AACC (2000) methods 44-15.02, 08-01.01 and 02-32.02, respectively. Radical scavenging capacity, flavonoid, and total phenolic content of the biscuits were determined using the same method described by Van Hung *et al*. (2009) and Velioglu *et al*. (1998), respectively.

Spread Ratio

Height (cm) and width (cm) of the biscuits (five samples each time) were measured using an accurate Vernier caliper (0.05 mm accuracy, Conventional Model, Inox, Bulgaria) and spread ratio of the samples was determined according to Equation (1) (Manohar and Haridas Rao, 1997).

$$\text{Spread ratio} = \frac{\text{Width of the biscuit}}{\text{Height of the biscuit}} \quad (1)$$

Density

The volume was measured using rapeseed displacement method according to the AACC (2000) method 10-05. Then, the density was measured by dividing the weight of the biscuit by its volume.

Surface Color

A sealed plastic box (50×50×60 cm) with interior white color containing a lamp with white light fixed at inside top door was prepared. Each biscuit was placed inside the box with a fixed distance of 50 cm from the lamp. A digital camera (Canon, Model IXUS 230 HS, 14.0 Megapixels, Japan) was placed vertically at 25 cm distance from the sample. The angel between the lens and the sample was 45°. The resolution, contrast, and lightness of all images were set to 300 dots per inch (dpi), 62, and 62%, respectively. Pictures were taken from the surface of each sample, saved in JPEG format and analyzed quantitatively using the Adobe Photoshop 11 software and the color parameters including "*L*" (Lightness), "*a*" (redness-greenness) and "*b*" (blueness-yellowness) were determined in the "Lab" mode of the software (Afshari-Jouibari and Farahnaky, 2011).

Textural Properties

Textural properties of the biscuits were studied using a triple point bending test by a texture analyzer (Texture Analyser, TA Plus, Stable Microsystems, Godalming, Surrey, England). Each biscuit with known dimensions was fractured using a three point bending probe. The experimental conditions were trigger force of 5 g-force, pretest speed of 5 mm s^{-1}, test speed of 5 mm s^{-1} and distance between supports of 25 mm. Each biscuit was placed on the platform and the probe moved down on the center point of the sample until its break point. Force versus deformation was plotted and Young's modulus was determined using Equation 2 (Bourne, 2002).

$$E = \frac{a^3}{4bh^3} \times \frac{F}{d} \quad (2)$$

Where, E is the Young's modulus (kg m^{-2}); F is the force (kg); a is the distance between two supports (m); d is deflection (m); b is the average biscuit thickness (m), and h is the average width of the biscuit (m).

Sensory Evaluation

Sensory attributes of the samples were evaluated using a five-point hedonic test with 24 semi-trained panelists**.** The biscuits stored for 24 hours at ambient temperature were evaluated for color, texture, taste, and overall acceptability. Samples were coded with three random digits and presented to the panelists. The panelists were asked to evaluate the samples and score them between 1 (most disliked) to 5 (most liked). The test was conducted in an appropriate booth under day light illumination for color evaluation and under red light for other organoleptic characteristics (Watts *et al*., 1989).

Statistical Analysis

The tests were performed at least in triplicates. A completely randomized design was utilized to determine significant differences among samples from Analysis Of Variance (ANOVA) to compare the difference in mean values for each characteristic. Duncan's multiple range test (P< 0.05) was used to determine the significances within treatments. To compare the differences between the two means obtained for different characteristics of DS and DLS samples, T-test was used. The statistical software of Statistical Analysis System 9.1 (SAS) was used for statistical analysis.

RESULTS AND DISCUSSION

Chemical Composition of DS and DLS

Chemical composition of the DS and DLS depends on the date fruit variety, their production method, and the method used for chemical composition determination. The chemical composition of the DS obtained in this study (Table 1) was close to the values reported previously (Al-Farsi *et al*., 2008). The main minerals in the DS were Ca, Mg, and Na (370.3, 251.3, and 75.30 mg kg^{-1}, respectively). Similarly, DLS was dominated by Ca, Mg, and Na (328.9, 175.6, and 15.03 mg kg^{-1}, respectively). Other minerals including Fe (2.79 mg kg^{-1}), Zn (2.43 mg kg^{-1}), Cu (0.77 mg kg^{-1}) and Mn (0.64 mg kg^{-1}) existed in DS in trace amounts. These elements were also trace in DLS (1.51, 0.47, 0.46 and 0.01 mg kg^{-1} for Fe, Mn, Zn and Cu, respectively).

Comparison of the DS and DLS composition (Table 1) showed that DS had significantly (P< 0.05) higher ash *(*5.30 *vs.* 0.6%), protein (1.20 *vs.* 0.80%), phenolic content (0.83 *vs.* 0.35 mg g^{-1}) and antioxidant activity, i.e. lower *IC50*, (59.52 *vs.* 133.46) than DLS mainly due to the purification steps required for DLS production that partly eliminated these materials from the DLS. Both DS and DLS had acidic nature with pH values of 4.1 and 3.2, respectively. The organic acids (mainly malic, oxalic, citric, succinic, formic and isobutric acids) originating from date fruit or produced during production lower the pH of these products (Afshari-Jouibari and Farahnaky, 2011). The lower pH of DLS compared with the DS can be attributed to either removal of dispersed or insoluble materials of amphoteric nature or structural changes of some acidic compounds of DS during the treatments to convert DS to DLS. The DLS had significantly (P< 0.05) higher

Table 1. Proximate composition of Date Syrup (DS) and Date Liquid Sugar (DLS).[a]

Component		DS	DLS
Moisture (%)		25.3±0.3[b]	27.1±0.2[a]
Ash (%)		5.30±0.51[a]	0.60±0.03[b]
Mineral content (mg kg^{-1})	Fe	2.79±0.70[a]	1.51±0.30[b]
	Mn	0.64±0.04[a]	0.47±0.44[b]
	Mg	251.3±19.01[a]	175.6±0.22[b]
	Cu	0.77±0.01[a]	0.01±0.00[b]
	Zn	2.43±0.40[a]	0.46±0.01[b]
	Ca	370.3±12.8[a]	328.9±9.4[b]
	Na	75.30±21.40[a]	15.03±0.83[b]
Protein (%)		1.20±0.40[a]	0.80±0.08[b]
Total soluble solid (%)		75.01±1.30[a]	72.51±3.20[a]
pH		4.1±0.1[a]	3.2±0.1[b]
Total phenolic content (mg g^{-1})		0.83±0.07[a]	0.35±0.05[b]
Total flavonoids content (mg g^{-1})		0.12±0.01[a]	0.14±0.01[a]
IC50 sample/*IC50* TBHQ solution		59.52±3.31[b]	133.46±6.31[a]
Fructose (%)		24.45±0.30[b]	26.34±0.50[a]
Glucose (%)		26.98±0.50[b]	32.62±0.40[a]

Mean ± standard deviation. Different superscripts in each row indicate statistical difference (P<0.05).

[DOR: 20.1001.1.16807073.2016.18.3.11.3]

glucose (32.62 *vs.* 26.98%) and fructose (26.34 *vs.* 24.45%) content than DS, however, they had similar amounts of flavonoid (0.12 and 0.14 mg g^{-1}) and total soluble solids (75.01 and 72.51%).

Dough Properties

Table 2 shows the pH values and moisture content of the dough. A significant decrease (P< 0.05) in the pH value from 7.13 (for the control) to 6.75 and 6.68 (for 100% substitution with DS and DLS, respectively) was observed which is related to the low pH value of the DLS and DS. At each substitution level, dough made with DLS had lower pH value compared with the DS due to its lower pH value. However, the moisture content of all samples was about 19.5% without any significant difference (P< 0.05).

Textural properties of the dough are given in the Figure 1. As the results show, the hardness of the dough decreased as a function of increment in the sucrose concentration. In biscuit dough, sugar competes with proteins and reduces gluten network formation. Such effect depends upon sugar type and its solubility. In addition, the limited amount of water in the biscuit dough and its non-accessibility to protein hider proper gluten network formation. At ambient temperature, the solubility of sucrose is higher than glucose, but lower than fructose. Nevertheless, when a mixture of the glucose and fructose is used (as in DS or DLS), the solubility of the mixture is greater than that of the individual sugars due to the less intra-molecular hydrogen bonds between different sugars (Gallagher *et al*., 2003; Parey *et al*., 2008). Therefore, in the dough containing DS and DLS, weaker gluten network is formed since most of the water is absorbed by the sugars resulting in softer dough compared to the control. Reduction of the dough pH caused by DS and DLS can further soften the dough. Similar results were reported for biscuit dough prepared with partial substitution of sucrose with reducing sugars including fructose, liquid glucose and invert sugar (Manohar and Haridas Rao, 1997). The presence of more protein and minerals in the DS further prevents gluten network formation resulting in softer dough than the DLS. This effect was more obvious at high concentrations (> 40%).

The results also showed that the adhesiveness (or stickiness) of the dough increased with reducing sucrose concentration. The dough made with DLS was more adhesive than the sample made with DS. This could be related to the more sticky nature of the DS and DLS (particularly DLS) and also because of more sugar going into the solution. Generally, dough of high adhesiveness is stickier and of lower handling properties and machinability which can reduce the quality of the biscuit (Hussin, 1995; Dobraszczyk, 1997; Laguna *et al*., 2013). Similar findings were observed for cookie and biscuit dough when sucrose was partially replaced by high fructose corn

Table 2. pH and moisture contents of the dough containing different levels of Date Syrup (DS) and Date Liquid Sugar (DLS).[a]

Substitution level (%)	pH		Moisture (%)	
	DS	DLS	DS	DLS
0	7.13 ± 0.04^{aA}	7.13 ± 0.04^{aA}	19.56 ± 0.19^{aA}	19.56 ± 0.19^{aA}
20	6.97 ± 0.03^{bA}	6.97 ± 0.05^{bA}	19.47 ± 0.18^{aA}	19.53 ± 0.12^{aA}
40	6.91 ± 0.01^{bA}	6.87 ± 0.04^{cA}	19.67 ± 0.18^{aA}	19.59 ± 0.16^{aA}
60	6.83 ± 0.02^{cA}	6.81 ± 0.06^{cA}	19.57 ± 0.10^{aA}	19.58 ± 0.10^{aA}
80	6.82 ± 0.01^{cA}	6.73 ± 0.01^{dB}	19.73 ± 0.13^{aA}	19.62 ± 0.14^{aA}
100	6.75 ± 0.03^{dA}	6.68 ± 0.02^{eB}	19.87 ± 0.12^{aA}	19.78 ± 0.18^{aA}

[a] Mean±Standard deviation. For each characteristic, different small letters in each column and capital letters in each row show the statistical difference (P< 0.05).

[DOR: 20.1001.1.16807073.2016.18.3.11.3]

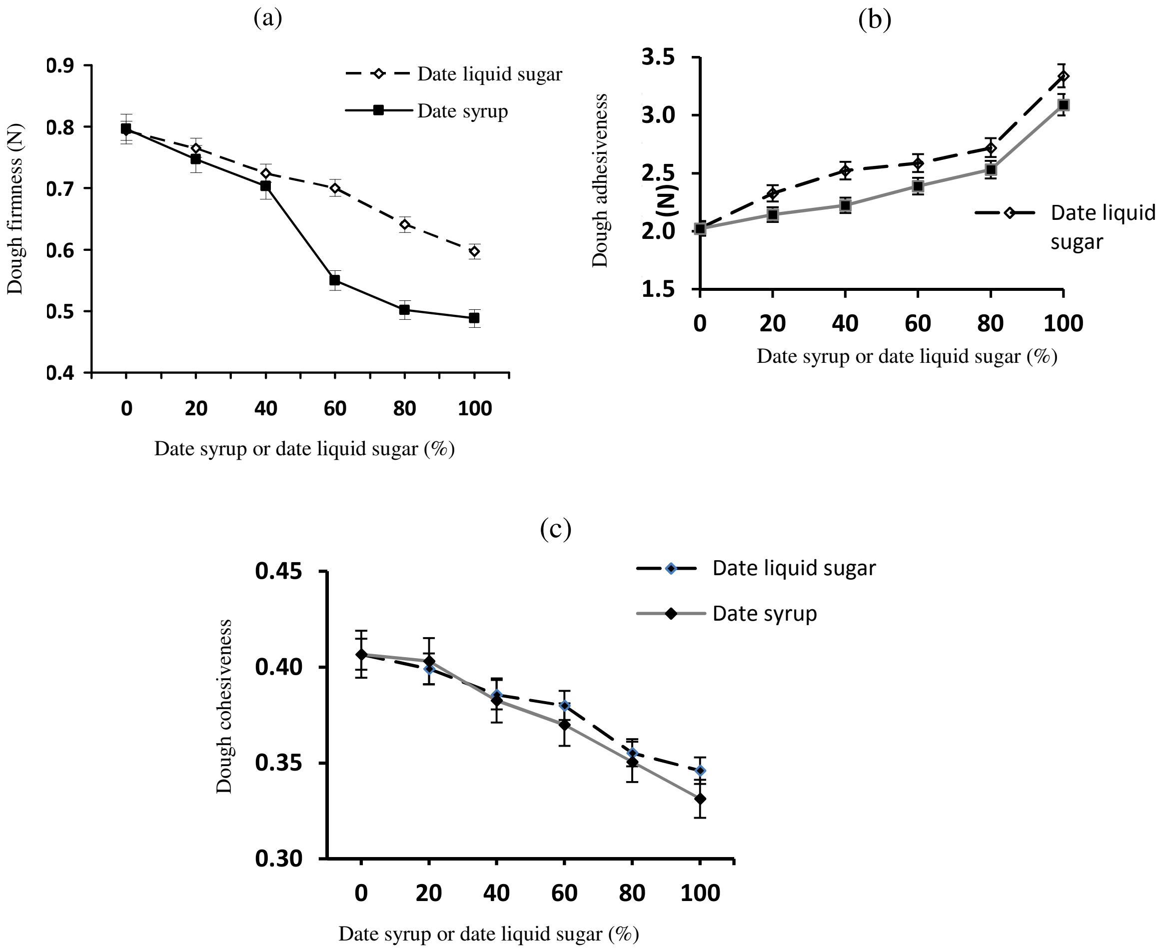

Figure 1. Firmness (a); adhesiveness (b), and cohesiveness (c) of the biscuit dough containing different levels of date syrup or date liquid sugar.

syrup, liquid glucose, and invert sugar (Manohar and Haridas Rao, 1997).

Cohesiveness shows the structural integrity of the dough. The results showed that the dough became less cohesive as the sucrose content decreased. No significant difference between the cohesiveness of the dough containing DLS or DS was observed.

pH, Ash and Moisture Contents of the Biscuits

Table 3 shows the pH, moisture, and ash contents of the biscuits. The pH of the control was 7.07 and decreased significantly (P< 0.05) after addition of different levels of DLS or DS. No significant difference (P< 0.05) between the pH values of the biscuits containing various amounts of DS or DLS was observed. The pH lowering effect of the DLS and DS is related to their acidic nature. However, further reduction of the pH was avoided possibly due to the presence of sodium bicarbonate and sodium pyrophosphate in the biscuit formulation with alkaline nature.

Addition of DS and DLS significantly (P< 0.05) increased the ash content of the biscuits. The ash content of the control was 1.45% and increased to 1.95 and 1.55% after 100% sucrose substitution with DS and DLS, respectively. At each substitution level, biscuits made with DS had higher ash content than the DLS counterparts because of DS higher minerals content.

Table 3. pH, ash and moisture contents of the biscuits containing different levels of Date Syrup (DS) and Date Liquid Sugar (DLS).[a]

Substitution level (%)	pH		Ash (%)		Moisture (%)	
	DS	DLS	DS	DLS	DS	DLS
0	7.07±0.04^{aA}	7.07±0.04^{aA}	1.45±0.09^{dA}	1.45±0.09^{aA}	3.85±0.04^{cA}	3.85±0.04^{cA}
20	6.84±0.04^{bcA}	6.85±0.03^{bcA}	1.49±0.06^{dA}	1.42±0.06^{aB}	3.95±0.06^{cA}	3.87±0.02^{cA}
40	6.80±0.04^{bcA}	6.83±0.02^{bcA}	1.53±0.03^{dA}	1.43±0.08^{aB}	4.12±0.09^{bA}	3.99±0.05^{cA}
60	6.76±0.06^{cdA}	6.77±0.06^{cA}	1.62±0.03^{cA}	1.52±0.07^{aB}	4.17±0.02^{bA}	4.12±0.03^{bA}
80	6.70±0.07^{dA}	6.75±0.01^{cA}	1.72±0.01^{bA}	1.56±0.01^{aB}	4.29±0.05^{aA}	4.20±0.02^{bA}
100	6.58±0.02^{eA}	6.62±0.02^{dA}	1.95±0.08^{aA}	1.55±0.04^{aB}	4.44±0.08^{aA}	4.35±0.13^{aA}

[a] Mean±Standard deviation. For each characteristic, different small letters in each column and capital letters in each row show the statistical difference (P<0.05).

Reducing the sucrose content resulted in biscuits with higher moisture content, however, the moisture content of the samples made with DS or DLS were the same. The control had a moisture content of 3.85%, which increased significantly (P< 0.05) to a maximum of 4.44 and 4.33% when 100% of sucrose was substituted with DS and DLS, respectively. Similar results were reported by Fahloul *et al*. (2010) by replacing 20, 40, and 60% of sucrose with date fruit powder in biscuits and Ahmadi *et al*. (2011) who replaced 50 and 100% DLS with invert syrups in cakes. Differences in the moisture content of the biscuits can be related to the different solubility rate of fructose, glucose, and sucrose during dough preparation. Sucrose remains mostly in the crystalline form with little interaction with water. Therefore, during baking, more water can evaporate readily before sucrose solubilization, leading to a drier biscuit. In contrast, glucose and fructose have more interactions with water and prevent it from evaporation during baking, leading to biscuits with higher moisture content. In addition, starch gelatinization can bind water and prevent it from rapid evaporation during baking (Spies and Hoseney, 1982). If starch gelatinization occurs earlier, most of the water is absorbed by the starch and will remain in biscuits. It has been shown that different sugars can delay starch gelatinization, however, the effect varies depending on the sugar type. Having a mixture of different sugars has an effect that is principally related to their type and concentration (Torley and van der Molen, 2005; Wang and Jane, 1994). In complex systems like DLS and DS where other components such as organic acids, proteins, and minerals are also present, starch gelatinization behavior is rather difficult to explain and needs further investigations. However, using amylograph, the effect of DS on the starch gelatinization and pasting characteristics of cake flour has been studied (Almana and Mahmoud, 1991). It was found that the DS delayed gelatinization, but to a lesser extent than did sucrose. Therefore, early starch gelatinization prevents water evaporation during baking resulting in biscuits with higher moisture content.

Biscuit Density and Spread Ratio

In general, biscuits of lower density are crispier and have more acceptable mouthfeel. Determination of the biscuit density (Table 4) showed that the biscuits became significantly (P< 0.05) denser as the sucrose concentration declined. Several factors can affect biscuit density including dough rheological properties, starch gelatinization and retrogradation behavior and the moisture content. Dough with soft texture may expand rapidly during baking, but it may shrink

[DOR: 20.1001.1.16807073.2016.18.3.11.3]

quickly after baking as it cools down at ambient temperature resulting in a dense structure. It was the case for the samples prepared with DLS and DS (see Figure 1-A) particularly at levels greater than 40%. In addition, the increase in the moisture content of the DS and DLS biscuits (see Table 3) can positively affect the density by increasing the weight and reducing the volume. The effects of DLS and DS on starch gelatinization and retrogradation can affect biscuit density that needs further investigation.

The results (Table 4) revealed that the spread ratio increased with decreasing sucrose content. Similar results were observed when sucrose was substituted with liquid glucose, high fructose corn syrup, and invert sugar (Almana and Mahmoud, 1991). In this study, the width and length of the biscuits remained unchanged as the level of DS or DLS increased (data not given), therefore, the increase in the spread ratio was due to the decrease in the biscuit thickness. At substitution levels higher than 40%, the spread ratio of the DS biscuits became higher than the DLS samples, which indicates the lower volume of these samples and affirms the density results.

Textural Properties of Biscuits

Young's modulus is an indication of biscuit hardness. Based on the results (Figure 2), reducing the sucrose concentration resulted in softer biscuits. Similar results for the effects of sucrose replacers on biscuits and cookies have been reported (Gallagher *et al.*, 2003; Mariotti and Alamprese, 2012). Higher crystallization rate of sucrose during cooling of the biscuits compared to the fructose and glucose is a reason for harder texture of the biscuits containing sucrose (Olinger and Velas, 1996). In addition, higher moisture content of the DS and DLS biscuits (see Table 3), plasticizing effect of fructose and glucose originated from DS and DLS and dough textural properties can reduce biscuit hardness (Wang and Jane, 1994). Comparing the Young's modulus of the DS and DLS samples, it was found that the DS biscuits were more fragile and had less compact structure, mainly due to the differences in the dough textural properties and chemical composition.

Biscuit Color

The color of the biscuits is due to the Maillard and caramelization reactions during baking. A key element in Maillard reaction is reducing sugar which is abundant in DLS and DS able to enhance the brown color. The results (Table 5) showed that the surface Lightness (L-value) decreased significantly (P< 0.05) with increasing the levels of DLS and DS. The *L*-value of the DS biscuits

Table 4. Density and spread ratio of the biscuits containing different levels of Date Syrup (DS) and Date Liquid Sugar (DLS).[a]

	Density (g cm^{-3})		Spread ratio	
Substitution level (%)	DS	DLS	DS	DLS
0	0.723 ± 0.009^{bA}	0.723 ± 0.009^{cA}	4.39 ± 0.02^{eA}	4.39 ± 0.03^{cA}
20	0.745 ± 0.440^{bA}	0.743 ± 0.003^{bcA}	4.44 ± 0.03^{dA}	4.40 ± 0.02^{cA}
40	0.787 ± 0.057^{abA}	0.791 ± 0.002^{abcA}	4.52 ± 0.04^{cA}	4.46 ± 0.03^{bA}
60	0.838 ± 0.055^{abA}	0.802 ± 0.055^{abB}	4.60 ± 0.04^{bA}	4.50 ± 0.03^{bB}
80	0.864 ± 0.090^{bA}	0.825 ± 0.003^{aB}	4.71 ± 0.03^{aA}	4.62 ± 0.02^{aB}
100	0.883 ± 0.090^{aA}	0.850 ± 0.011^{aB}	4.73 ± 0.03^{aA}	4.65 ± 0.04^{aB}

[a] Mean±Standard deviation. For each characteristic, different small letters in each column and capital letters in each row show the statistical difference (P<0.05).

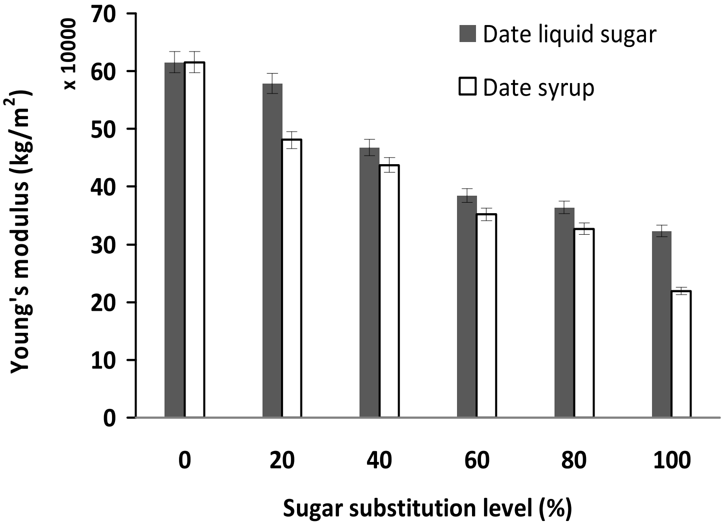

Figure 2. Young's modulus of the biscuits containing different levels of date syrup or date liquid sugar. Different letters on the bars indicate statistical difference (P< 0.05).

ranged from 30.3 to 35.0, while for the DLS samples it ranged from 32.6 to 35.0. Comparing the L-value of the samples, it was found that the samples containing DLS were lighter in color. The surface redness significantly (P< 0.05) increased with increasing the DLS and DS concentration (higher a-value). The *a*-value ranged from 12.6 to 15.6 for DLS biscuits and from 12.6 to 18.3 for DS samples. Therefore, replacement of sucrose with DLS resulted in more reddish samples. The yellowness (b-value) of the samples decreased significantly (P< 0.05) with increment in the DS or DLS concentration. With reducing sucrose level, the yellowness of the DS biscuits decreased from 57.6 to 35.3, while for the DLS samples it decreased from 57.6 to 41.6. The DLS biscuits were more yellowish than the DS counterparts. The darker color of the DS biscuits than DLS samples was related to the darker color of the DS and more compact structure of the DS biscuits.

Sensory Evaluation Results

According to Table 6, scores given to

Table 5. Color parameters of the biscuits containing different levels of Date Syrup (DS) and Date Liquid Sugar (DLS).[a]

Substitution level (%)	*L*-value (Lightness)		*a*-value (Redness-greenness)		*b*-value (Blueness-yellowness)	
	DS	DLS	DS	DLS	DS	DLS
0	35.0 ± 0.1[aA]	35.0 ± 0.1[aA]	12.6 ± 0.1[eA]	12.6 ± 0.1[cA]	57.6 ± 0.1[aA]	57.6 ± 0.1[aA]
20	33.0 ± 0.4[bB]	34.0 ± 0.4[bA]	13.6 ± 0.4[dA]	12.6 ± 0.6[cB]	52.3 ± 1.0[bB]	55.6 ± 1.0[bA]
40	32.6 ± 0.5[cB]	34.3 ± 0.2[bA]	15.3 ± 0.2[cA]	13.6 ± 0.3[bB]	46.3 ± 0.7[cB]	49.6 ± 1.0[cA]
60	31.3 ± 0.1[dB]	34.6 ± 0.5[bA]	15.0 ± 0.5[cA]	14.3 ± 0.5[aB]	44.3 ± 0.5[dB]	48.3 ± 0.8[cA]
80	31.0 ± 0.3[dB]	33.3 ± 0.1[cA]	16.6 ± 0.1[bA]	15.3 ± 0.1[aB]	39.0 ± 0.1[eB]	45.6 ± 0.1[dA]
100	30.3 ± 0.3[eB]	32.6 ± 0.2[dA]	18.3 ± 0.7[aA]	15.6 ± 0.7[aB]	35.3 ± 0.7[fB]	41.6 ± 0.5[eA]

[a] Mean±Standard deviation. For each characteristic, different small letters in each column and capital letters in each row indicate statistical difference (P< 0.05).

[DOR: 20.1001.1.16807073.2016.18.3.11.3]

texture, taste, color, and overall acceptability of the biscuits remained unchanged when up to 40% DS or 60% DLS were used. However, further addition of DS or DLS significantly (P< 0.05) reduced these scores. Increasing the DS and DLS levels reduced the scores given to the texture as the biscuits became denser. The panelists recognized a bitter taste at high sucrose replacement levels, mainly due to Maillard and caramelization products and probably the proteins and minerals in the DS and DLS, which could have undesirable taste. The color of the biscuits received high scores when up to 60% DS and 80% DLS were added. The overall acceptability of the samples decreased as they lost their taste, color, and mouthfeel.

The biscuits containing DLS received higher scores than those prepared with DS. This can be related to the presence of more impurities and darker color of DS which can have negative effects on color, texture, and taste of the biscuits.

Antioxidant Activity of the Biscuits

After determination of the appropriate sucrose substitution levels based on the sensory evaluation results, phenolic and flavonoid contents and *IC50* of the biscuits were determined (Table7). Phenolics and flavonoids are the most effective antioxidants with free radical scavenging activity, inhibiting hydrolytic and oxidative enzyme, and anti-inflammatory effects (Havsteen, 2002). Table 6 shows that the phenolic and flavonoid contents of the biscuits made with sucrose were 0.48 and 1.21 mg g^{-1}, respectively, which increased significantly (P< 0.05) to 0.74 and 1.86 mg g^{-1}as the sucrose was replaced with 40% DS. Similarly, sucrose substitution with 20, 40, and 60% DLS significantly (P< 0.05) increased phenolic and

Table 6. Sensory evaluation of the biscuits containing different levels of Date Syrup (DS) and Date Liquid Sugar (DLS).[a]

Substitution level (%)	Texture		Taste		Color		Overall acceptability	
	DS	DLS	DS	DLS	DS	DLS	DS	DLS
0%	4.5^{aA}	4.5^{aA}	4.4^{aA}	4.4^{aA}	4.7^{aA}	4.7^{aA}	4.6^{aA}	4.6^{aA}
20%	4.7^{aA}	4.6^{aA}	4.6^{aA}	4.3^{aA}	4.6^{aA}	4.5^{aA}	4.6^{aA}	4.7^{aA}
40%	4.4^{aA}	4.4^{aA}	4.4^{aA}	4.4^{aA}	4.4^{aA}	4.5^{aA}	4.5^{aA}	4.6^{aA}
60%	3.7^{bB}	4.5^{aA}	4.0^{bB}	4.6^{aA}	4.3^{aB}	4.4^{aA}	4.0^{bB}	4.5^{aA}
80%	3.6^{bB}	4.0^{bA}	3.5^{cB}	4.0^{bA}	3.6^{bcB}	4.3^{aA}	3.6^{cB}	4.0^{bA}
100%	3.3^{bB}	3.8^{bA}	3.2^{cB}	3.7^{bA}	3.3^{cB}	3.9^{bA}	3.2^{dC}	3.7^{bA}

[a] Mean of triplicates. For each characteristic, different small letters in each column and capital letters in each row indicate statistical difference (P< 0.05).

Table 7. Phenolic and flavonoid content and antioxidant activity of biscuits made with different levels of Date Syrup (DS) and Date Liquid Sugar (DLS).[a]

Substitution level	Phenol content (mg g^{-1})	Flavonoid content (mg g^{-1})	*IC50* sample/*IC50* TBHQ
0%	0.48 ± 0.02^{e}	1.21 ± 0.15^{f}	521.11 ± 31.15^{a}
20% DS	0.55 ± 0.01^{c}	1.58 ± 0.03^{b}	402.63 ± 21.10^{e}
40% DS	0.74 ± 0.02^{a}	1.86 ± 0.12^{a}	281.77 ± 22.16^{f}
20% DLS	0.50 ± 0.02^{d}	1.25 ± 0.05^{e}	511.31 ± 30.12^{b}
40% DLS	0.54 ± 0.04^{c}	1.36 ± 0.05^{d}	496.01 ± 25.14^{c}
60% DLS	0.65 ± 0.03^{b}	1.53 ± 0.05^{c}	453.81 ± 31.19^{d}

[a] Mean±Standard deviation. Different letters in each column indicate different statistical difference (P< 0.05).

[DOR: 20.1001.1.16807073.2016.18.3.11.3]

flavonoid contents of the biscuits. The maximum amount of phenolic and flavoloid contents were related to the biscuits produced with 40% DS. *IC50* of a sample is an indication of the antioxidant activity and the lower value corresponds to the higher antioxidant activity (Veliogslu*et al*., 1998). The results showed that the *IC50* of the samples decreased significantly ($P< 0.05$) as the level of sucrose substitution increased. The DS biscuits had lower *IC50* compared to the DLS biscuits. The biscuits prepared with DLS and DS biscuits had high antioxidant activity than the control.

CONCLUSIONS

Based on the results, it was concluded that the DS and DLS can be used in biscuit production in order to reduce sucrose consumption. Replacement of sucrose with a maximum of 60% DLS and 40% DS resulted in the samples with similar characteristics to the control, while further reduction in sucrose content resulted in inferior dough and biscuit quality. The physicochemical properties of dough and biscuits after inclusion of DS and DLS were different, however, the changes had similar trend. The DS dough was softer and less adhesive and had lower pH than the DLS counterpart. The DS biscuits had higher ash content and were softer and darker and had higher antioxidant content than the DLS biscuits. Although DS could reduce lesser amount of sucrose than DLS (40 *vs*. 60%), the product had higher mineral and antioxidant content. Even partial substitution of sucrose with DS and DLS can increase the antioxidant activity and mineral content of the biscuits. This is an important advantage of DS and DLS over sucrose and most of synthetic sugar replacers, in addition to their economical price in many countries.

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اثرات جایگزینی ساکرز با شربت خرما و قند مایع خرما بر ویژگی های فیزیکوشیمیایی خمیر و بیسکوئیت

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چکیده

به منظور کاهش مصرف ساکارز در تهیه بیسکوئیت، شربت خرما و قند مایع خرما در مقادیر مختلف (۰، ۲۰، ۴۰، ۶۰، ۸۰ و ۱۰۰٪) با ساکارز جایگزین شدند و ویژگی های فیزیکوشیمیایی خمیر و بیسکوئیت های حاصل مقایسه شدند. با افزایش مقدار شیره خرما و قند مایع خرما پی اچ خمیر و پیوستگی آن کاهش یافت در حالی که نرمی و چسبندگی خمیر افزایش یافت. پی اچ ، نرمی و چسبندگی خمیر نمونه های حاوی قند مایع خرما بیشتر شد. بیسکوئیت های تهیه شده با خمیر مایع خرما و قند مایع خرما پی اچ کمتر، خاکستر و رطوبت بالاتر از بیسکوئیت های دارای ساکارز بودند. بیسکوئیت های دارای شربت خرما دارای خاکستر بیشتری از نمونه های دارای قند مایع خرما بودند. افزودن شربت خرما و قند مایع خرما باعث افزایش دانسیته، ضریب پخش، بافت سفت تر و تیرگی بیشتر محصول شد. این تغییرات در مورد نمونه حاوی شربت خرما بیشتر بود. جایگزینی ساکارز با مقادیر کمتر از ۴۰٪ شربت خرما یا ۶۰٪ قند مایع خرما منجر به تولید بیسکوئیت هایی با ویژگی های حسی شبیه به نمونه کنترل شد در حالی که ترکیبات آنتی اکسیدانی و املاح بیشتری بود.

[DOR: 20.1001.1.16807073.2016.18.3.11.3]