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Utilizing Non-Marketable Dates as a Sugar Substitute in Producing Nutritionally Balanced Functional Biscuits

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Abstract

Dates are an important national resource in Saudi Arabia, with significant efforts focused on increasing production, enhancing quality, and utilizing surplus dates for health-oriented food products. This study investigates the technological role of powdered low-quality Sukkari dry dates as a sugar substitute in balanced functional biscuits that are rich in fiber and minerals while being low in calories. The study assessed the effects of substituting sugar with powdered dates at levels of 25%, 50%, and 75%, focusing on the optimal substitution ratio for high-quality biscuits. The findings revealed that the powdered date substitution influenced the dough's rheological properties, including a decrease in water absorption, an increase in dough formation time, and a reduction in mixing tolerance at higher substitution levels. The sugar reduction led to a decrease in calories and carbohydrates, while protein and ash content increased. Color analysis showed reduced lightness and yellowness, with an increase in redness and darker tones as the substitution level rose. Sensory evaluations indicated that biscuits with 25% substitution were highly acceptable, scoring 94.90%, comparable to the control sample's 97.15%. Biscuits with up to 50% substitution were also deemed acceptable, highlighting the potential of Sukkari dates as a balanced functional and healthier sugar alternative in biscuit production.

Keywords: Balanced functional Biscuits; Sukkari Dates; Date Powder; Nutritional Value; Sugar Substitute; Low-Sugar Biscuits

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1. Introduction

Date palms are among the oldest fruit-bearing trees in the world and have been deeply intertwined with human life in the Middle East, particularly in Saudi Arabia, since ancient times. Their prominence stems from two main factors: the region's desert climate and the expertise of Saudi farmers. Dates are highly nutritious, packed with carbohydrates, fiber, minerals, and essential vitamins, including vitamin B. This has sparked growing interest in their health benefits, leading to creation of food products that incorporate dates as a nutrient-dense ingredient. However, an estimated 20–30% of dates wasted annually due to being unsuitable for marketing or surplus production from previous years, leaving much of their nutritional potential untapped in high-value food applications [8]. Saudi Arabia's Vision 2030 has placed significant emphasis on palm and date sector, focusing on its development and sustainability. In 2021, Saudi Arabia ranked first globally in date exports. Dates are among most important national resources for Gulf countries, contributing to individual national income and serving as one of strategic crops compete globally in date production and processing.

Dates are economically viable for Saudi Arabia due to favorable climatic conditions, suitable soil, and extensive cultivation areas. With growing global recognition of their nutritional value and health benefits, the demand for dates is expected to rise, along with their application in the food and medical industries. Transformative industries that utilize date derivatives are also economically beneficial. By efficiently utilizing surplus dates and byproducts, the Kingdom can enhance local value-added industries, align with global advancements in date processing, improve product quality, and potentially reduce the need to import raw materials. For example, dates can serve as an alternative to sugar due to their high sugar content [8-23-43-46]. [11], the average sugar content of ten types of Saudi dates ranges between 71.2% and 81.4% of their dry weight. They are also rich in essential minerals such as selenium, copper, potassium, and magnesium, and they are a significant source of B-complex vitamins and vitamin C. Each mineral's percentage in dried dates varies from 0.1 to 916 mg/100g of date flesh [9]. Dates flesh contains a high percentage of potassium, as it is the predominant microelement in them [14].

They also contain low levels of sodium and high concentrations of iron [24]. Dates contain a wide range of vitamins such as vitamin A, B1, B2, B3, B5, and vitamin C. Dates contain vitamin A, which possesses antioxidant properties [24]. Additionally, dates contain a high dietary fiber content of up to 8.0 g per 100 g and are an excellent source of antioxidants, particularly carotenoids and phenolic compounds [7]. Rich nutritional content, fiber, &antioxidants in dates have made them one of most important strategic and food products. Dates are consumed directly or transformed into various forms to create valuable food products. For instance, date powder can be used as a natural sweetener and as a key ingredient in the production of baked goods and desserts. Their high fiber content is particularly beneficial in developing functional foods such as biscuits, cakes, and pastries, making them suitable for children, elderly, and those interested in consuming healthier products [56]. Unhealthy eating habits, such as consuming foods high in sugars and fats but low in fiber, combined with insufficient physical activity can lead to health issues like obesity and elevated blood sugar levels [39]. A study conducted at Taibah University in Madinah evaluated the chemical composition of ten date varieties grown in Saudi Arabia to assess their nutritional content (including crude protein, crude fat, and ash).

For the Sukkari date variety, results showed moisture content of 21.2%, ash at 3.37%, and low concentrations of protein (2.76%) and fat (0.52%), with an average total sugar content of 78.5% [11]. Several researchers, including [26-39], highlighted the experimental use of dates in various products, such as baked goods. They found that replacing sucrose with dates in bread and biscuits improved their nutritional value by increasing mineral and vitamin levels. [34], noted that one cup of date sugar, made by drying and grinding dates into a powder, is equivalent to one cup of brown sugar and can replace white sugar at a 1:1 ratio [46]. Additionally, integrating secondary date products has been essential, with several derivatives developed to partially replace wheat flour in bread and flour production [58]. In a study by [46], on impact of replacing sucrose with date powder on bread quality, sucrose was substituted at levels of 50:0g, 37.5:12.5g, 25:25g, 12.5:37.5g, and 0:50g. Chemical analysis showed increases in protein (15.19–19.43%), crude fiber (1.65–4.43%), ash (2.44–4.11%), and moisture content (28.19–28.92%) with higher levels of date pulp substitution. However, carbohydrate content decreased from 45.39% to 35.13%. Addition of date powder did not affect loaf volume.

A sensory evaluation conducted by a panel of 25 experts found all 84 bread samples to be acceptable, concluding that substituting sucrose with date pulp powder enhanced the nutritional value of the bread samples. Similarly, a study in Nigeria by [12], examined the effect of replacing sugar with date powder on the nutritional and sensory qualities of bread. Sucrose was replaced at 100:0%, 50:50%, and 0:100%. Results showed that the 100% sucrose sample had the highest carbohydrate (61.90%) and fat (3.73%) contents, whereas the 100% date powder sample had the highest protein (6.27%), ash (3.67%), and fiber (2.03%) contents. It also had highest levels of calcium, phosphorus, iron, zinc, and selenium. Sensory evaluation indicated highest overall acceptance for control sample, followed by others in descending order. However, study recommended 50:50% and 0:100% sucrose-to-date powder ratios for bread production, highlighting their broad nutritional benefits and positive health, social, and economic impacts. The Sukkari date variety is one of most popular and significant varieties cultivated in Saudi Arabia, primarily grown in key regions like Qassim. Its cultivation is favored due to its high quality and substantial economic returns for farmers and consumers alike [23].

In Arab countries, particularly, Sukkari dates are considered among the finest date varieties. They are easily distinguished by their unique color and are named for their extra sweetness that adds to taste experience [53]. Date fruits and their derivatives are rich in bioactive compounds with potential health benefits, making them suitable as food ingredients in various products. Incorporating dates into the food industry can help meet growing consumer demand for products made with natural ingredients [24]. Biscuits are an important baked product due to their variety in flavor, texture, and aroma. They are low-moisture foods with an extended shelf life and affordability. Typically made from wheat flour, fat, and sugar, biscuits are known for their high fat content, which contributes to their distinctive texture and flavor. Wheat flour is primary ingredient due to its gluten content; however, it is high in starch and low in dietary fiber and minerals, resulting in biscuits with lower nutritional value [57]. There has been a growing demand for health-oriented products, such as sugar-free, low-calorie, and fiber-rich foods. One emerging trend involves increasing dietary fiber content in foods to address health concerns like hypertension, diabetes, and colon cancer.

Consuming foods rich in dietary fiber, including indigestible cellulose, hemicellulose, lignin, and gums, has numerous health benefits [56]. Biscuits, being widely consumed and affordable, ideal for nutritional enhancement but are often deficient in essential nutrients [37]. Using date powder as a sweetener is a promising alternative to sugar in biscuits. Traditionally, sugar is added at 50g per 100g of wheat flour. A study explored sugar replacement with date powder at varying levels (20%, 40%, 60%, and 80%), observing that replacing more than 30% resulted in a firmer texture due to higher fiber content and an undesirably darker color. However, a 60% reduction in sugar, replaced by date powder, showed no significant effect on sensory properties, making such biscuits nutritionally superior [18]. In another study on date powder-enriched cookies (Samani variety), addition of date powder at 5%, 10%, 20%, and 40% showed increases in crude fiber, ash, and moisture content with higher replacement levels. However, physical properties like color decreased with higher proportions. Sensory evaluation revealed that cookies with 40% date powder were less acceptable, while those with 10% addition maintained desirable color, taste, texture, and overall acceptance. Study recommended a 10% inclusion rate to boost nutritional value without compromising cookie quality [12].

Research by [33], investigated biscuits made from whole wheat flour and palm fruit pulp at different proportions. The study found that replacing sugar with palm fruit pulp improved flour properties, such as swelling index, oil absorption capacity, and viscosity, compared to control samples. Chemical composition also improved with higher pulp addition, while fracture resistance decreased. A 70:30 wheat-to-palm fruit ratio was deemed optimal. This highlights the potential of using date pulp as a sugar substitute in biscuits and other baked goods, as it provides sweetness and enhances nutritional properties. Sucrose not only provides sweetness in biscuits but also influences texture,

structure, and color during processing [60]. Although reducing sugar levels in baked goods poses challenges due to its functional roles, developing healthier alternatives is a growing research focus [14-29]. The increasing awareness of dietary fiber's health benefits has led to a substantial market for fiber-enriched products. Dietary fiber, defined by AOAC International as "plant-based residues resistant to hydrolysis (digestion) by human digestive enzymes," offers numerous health advantages [17]. High fiber intake is associated with reduced risks of coronary artery disease, heart conditions, hypertension, obesity, and certain cancers. It also aids in digestive health and detoxification [13].

Fiber incorporation in foods like baked goods, jams, soups, and meats improves their water and oil retention, emulsification, and gel-forming abilities, enhancing both functionality and shelf life [19]. However, daily fiber consumption often falls short of recommended levels, typically 25–30g/day according to the USDA. Strategies to include fiber in widely consumed products, such as biscuits, are crucial for addressing this gap [52]. Dates in Saudi Arabia are a vital national resource and strategic crop, with the Kingdom focusing on increasing production, improving quality, and utilizing surplus dates and their by-products through processing industries. The high sugar and fiber content of dates makes them ideal for developing food products targeted at children, elderly, and health-conscious consumers. This study aims to utilize low-quality dry Sukari dates, converted into date powder, as a sugar substitute in production of nutritionally balanced, cost-effective functional biscuits. Objective is to enhance nutritional value, improve sensory and physical qualities, and evaluate the impact of date powder on dough rheology and biscuit quality.

2. Materials and Methods

2.1. Materials

Dry Sukkari dates unsuitable for packaging, processing, or marketing were obtained from Al-Butain Date Factory in Buraidah, Al-Qassim region. The raw materials for biscuit preparation, including fine wheat flour (72% extraction), fine granulated table sugar (sucrose), shortening, milk powder, baking powder, baking soda, vanilla, and pure iodized salt, were sourced from the local market in Unaizah, Al-Qassim, Saudi Arabia. High-purity chemicals required for research were procured from Sigma in Riyadh, Saudi Arabia.

2.2. Methods

2.2.1. Preparation of dry Sukkari Date Powder

The Sukkari date powder produced using non-marketable dry dates as follows:

1. Sorting: Dates were received, sorted thoroughly, and any impurities, bird-damaged, insect-infested, or moldy fruits were discarded.
2. Cleaning: Dates were passed through rollers equipped with soft brushes, and an air stream used to remove dust.
3. Crushing and Grinding: The dates crushed to remove pits using a crushing machine. The date flesh then ground in a mill with a cooling system to prevent clumping.
4. Sieving: The ground date powder was sieved to remove coarse particles and achieve the desired particle size suitable for biscuit production.
5. Packaging: The powder was packed in moisture-proof polyethylene bags until use.

2.2.2. Rheological Properties of Biscuit Dough

The rheological behavior of the dough mixtures was studied using a Farinograph (type 810107, the Brabender OHG, Duisburg, Germany) following the method outlined by [2]. The results were used to estimate the water absorption, assess the effects of ingredients on the dough mixing properties, and predict dough quality during the production. The partial substitution of the sugar with the date powder was evaluated.

2.2.3. Biscuit Preparation

Biscuit samples were prepared, including a control sample, by replacing sugar with Sukkari date powder at substitution levels of 0%, 25%, 50%, and 75%. The biscuits were manufactured according to the ingredients in Table No. (1) and their amounts, following method described by [38]:

1. Mixing: Sugar or date powder and shortening creamed together using a kitchen mixer (Kenwood, HM 1010 model, Beijing, China) at 125 rpm (speed 4) for 6 mins.
2. Adding Dry Ingredients: Flour mixed with sodium bicarbonate, ammonium bicarbonate, milk powder, and salt was gradually added to the creamed mixture and mixed for 4 minutes, along with the amount of water determined using the Farinograph.
3. Rolling and Cutting: The dough was rolled to a thickness of 0.5 cm and cut into round shapes (5.5 cm diameter).
4. Baking: The biscuits baked at 180 ± 4°C for 15 minutes.
5. Cooling and Storage: The Biscuits were cooled and packed in polyethylene bags and stored at room temperature until analysis.

2.2.4. Quantitative Estimation of Sugars

The sugar content of date powder and biscuit samples was determined using the method outlined by [1].

2.2.5. Chemical Composition and Caloric Content

The chemical composition (moisture, ash, total protein, fat, crude fiber, and carbohydrates) of the date powder and biscuit samples analyzed following [1] methods. Protein content was measured using the Kjeldahl method, with a conversion factor of 5.70 for wheat flour and 6.25 for both date powder and biscuits. Fat content was determined using a Soxhlet apparatus. Carbohydrate content was calculated using equation (1).

$$Carbohydrates\ (\%) = 100 - (\%\ protein + \%\ fat + \%\ ash + \%\ crude\ fiber) \quad (1)$$

Caloric content was estimated based on the energy values of protein (4 kcal/g), carbohydrate (4 kcal/g), and fat (9 kcal/g). Thus, total calories estimated using equation (2).

$$Total\ calories = N.of\ grams \times kcal/gram \quad (2)$$

2.2.6. Total Phenolic Content

The Phenolic - Content method, as outlined by [51], was used to measure the total phenolic content of biscuit samples using a UV/VIS spectrophotometer (model UV/VIS 1201, Shimadzu, Kyoto, Japan).

2.2.7. Physical Properties of Biscuits

1. Diameter and Thickness

The diameter of the biscuits was measured by taking the average of six biscuits, rotating each by 90° for accuracy. Thickness was determined by stacking six biscuits and calculating the average. The spread ratio was then computed

as the average diameter divided by the average thickness, following the method outlined by [2].

2. Color Properties

The surface color of date powder and biscuit samples analyzed using a Hunter Lab colorimeter to measure lightness (L), redness (a), and yellowness (b) as per [2].

3. Hardness

Biscuit hardness was measured using a texture analyzer (HD. Plus, Stable Micro System, and UK) following the method described by [39].

4. Water Activity

Water activity was assessed using an Aqua Lab analyzer (Decagon Devices Inc., Pullman, WA, USA) according to [5].

2.2.8. Sensory Evaluation

Sensory attributes such as appearance, surface color, internal color, texture, taste, aroma, and overall acceptability were evaluated by 10 panelists from the Food Science and Human Nutrition Department, College of Agriculture and Food, Qassim University. The evaluation followed the method outlined by [28].

2.2.9. Statistical Analysis

Statistical analysis was conducted using ANOVA followed by Duncan's Multiple Range Test ($P \leq 0.05$) using SAS (2004) software. Results were expressed as mean values with three replicates for most analyses, except spread ratio (6 replicates) and sensory evaluation (10 replicates).

3. Results and discussion

3.1. Results

3.1.1. Rheological Properties of Biscuit Dough Containing Different Levels of Sukkari Date powder

Table 2 shows the rheological test results using the Farinograph for biscuit dough containing different percentages of Sukkari Date powder (replacing 25%, 50%, and 75% of sugar). The obtained results are as follows:

3.1.1.1. Water Absorption (%)

Water absorption refers to the amount of water required for the flour-water mixture (dough) to reach the 500 Brabender units (B.U.) on the Farinogram. As shown in Table 2, the water absorption of the flour mixture decreased as the percentage of date powder replacement increased. The recorded values were 60.0%, 55.1%, and 51.1% for 25%, 50%, and 75% replacement of sugar with date powder, respectively, compared to the control dough which had a value of 65.0%. These results align with a study using Sokoti date powder as a sugar substitute in biscuit production at 20%, 30%, and 50% replacement levels, where it was observed that the reduced water absorption is due to the high level of reducing sugars (mainly fructose) in date powder, which creates a sticky mass when dissolved, aiding in reaching 500 (B.U.). In contrast, the control sample required more water to hydrate the starch and protein particles in the flour responsible for viscosity, with the study indicating that the water needed to mix the control sample was 59 cm^3/100g of flour, which gradually decreased to 42 cm^3/100g when 30% of the flour was replaced with Sokoti date powder [43].

3.1.1.2. Dough Development Time

This is the time (rounded to the nearest half-minute) from the addition of water to the dough until the dough reaches the consistency known as dough stability, just before it weakens. Table 2 shows an increase in the time required to develop the dough when date powder is added. The control sample required the shortest time (2.13 minutes), followed by the 25% and 50% replacement samples, which took 5.33 and 5.32 minutes, respectively. 75% replacement sample took longest time at 6.38 minutes. This is likely due to higher fiber content in date powder and its coarse particles, which require a longer mixing time for proper incorporation [43]. Additionally, [18] observed that the dough development time increases gradually with higher levels of wheat bran and date powder mixtures, reaching 6.04 minutes with a 40% replacement compared to control (2.5 minutes), & indicating need for more time with increasing replacement percentages.

3.1.1.3. Stability Degree

Stability is calculated as the difference between the arrival time and departure time on the Farinogram, which is the time from the first point at 500 (B.U.) to when it begins to fall away from this value. The control sample showed the highest stability duration at 13.28 minutes, while this value decreased with the higher replacement levels, reaching 4.58 minutes at 75% replacement. This decrease is attributed to the impact of date powder fibers on the gluten network in dough.

3.1.1.4. Tolerance Index

The tolerance index is measured in (B.U.), which is difference between peak time and peak value after 5 minutes. Resistance values increased with date powder replacement. The control sample recorded a value of 16 B.U., while samples with 25%, 50%, and 75% replacement recorded values of 71, 91, and 109 B.U., respectively. A lower tolerance index indicates better mixing ability, and it has been noted that higher replacement percentages weaken the dough and reduce its ability to withstand mixing [4]. A study investigating effect of palm fruit powder replacing sugar in dough properties also found that increasing replacement with palm fruit powder reduced dough's tolerance to mixing [48].

3.1.1.5. Farinograph Quality Number

The obtained results show that the control sample had the highest quality value at 141. This was followed by a decrease in the values, with the 25% replacement sample recording a quality value of 81, while the 50% and 75% replacement samples showed the lowest quality values of 79.

3.1.1.6. Quantitative Estimation of Sugars

The quantitative estimation of sugars in non-marketable Sukkari Date powder (grams per 100 grams of dry weight) was found as follows: Reducing sugars: 63.19%; non-reducing sugars: 1.43% and Total sugars: 64.62%. Table 3 illustrates the effect of replacing sugar with Sukkari Date powder on the quantitative estimation of sugars in biscuits. The results indicate significant differences in the reducing sugars between the three treatments of 25%, 50%, and 75% date powder substitution. The findings show an increase in reducing sugars with higher substitution levels, recording values of 0.79%, 1.58%, and 2.37% for 25%, 50%, and 75% replacements, respectively. Conversely, a significant decrease in non-reducing sugars was observed as the

substitution level increased. The non-reducing sugars decreased from 15.84% in the control sample to 10.32% in the 75% date powder substitution sample. There were significant differences in total sugars between the 50% and 75% date powder substitutions. However, no significant difference was observed between the control sample and the 25% date powder substitution. This trend aligns with the higher proportion of reducing sugars (about 70%) in date varieties in Saudi Arabia, which contain nearly equal amounts of glucose and fructose [29]. It is also known that most semi-dry dates have higher levels of reducing sugars [30].

3.1.1.7. Estimation of Chemical Composition and Caloric Value

Chemical analysis and calorie calculation of Sukkari date powder that the moisture content was 9.37%, while protein, ash, and fat content were 3.02%, 3.72%, and 0.20%, respectively. Additionally, the levels of carbohydrates and calories were 87.58% and 362.76 Calories (kcal/100g) respectively, on a dry basis (un-tabulated data). Table 4 shows the effect of replacing sugar with Sukkari Date powder on the chemical composition of the Biscuits. The results indicate significant differences in moisture content for the 75% date powder substitution, where the moisture level increased from 4.26% in the control sample to 6.69% in the 75% date powder substitution sample. These results are consistent with findings from the addition of date powder to cookies, where an increase in moisture content was observed with higher substitution levels, likely due to the higher sugar content which binds water in samples [10]. No significant differences were observed between control sample and 25% and 50% date powder substitutions. The results also showed significant differences in protein content b/w four treatments.

The highest protein content was found in the 75% date powder substitution sample, which had 7.58% protein, compared to 6.53% in the control sample. This suggests that increasing the substitution level improves the nutritional value of the Biscuits [30]. Additionally, the ash content increased with higher substitution levels, with the highest value of 1.88% in the 75% date powder substitution sample, compared to 1.22% in the control sample [11]. Regarding fat content, significant differences were observed among the four treatments, with fat content decreasing as the substitution percentage increased. The fat content decreased from 21.41% in the control sample to 20.18% in the 75% date powder substitution sample. Significant differences were also found in fiber content, which increased significantly from 2.32% in the control sample to 4.03% in the 75% substitution sample. Many studies have shown that dates are among the best sources of dietary fiber, which can enhance the nutritional quality of bakery products [3-34-50]. Regarding carbohydrates, there was a significant decrease as the substitution level of sugar with date powder increased.

Carbohydrate content gradually decreased with higher substitutions, with the 75% substitution sample having the lowest value at 66.33%, while the control sample had the highest value at 68.52%. No significant differences were found between the 25% and 50% substitution treatments. These results align with findings from [47]. The results also showed significant differences in caloric content among the four treatments. The calorie content decreased from 492.89 kcal/100g in control sample to 477.27 kcal/100g in the 75% date powder substitution sample. Glucose and fructose are main sugars in dates, with fructose helping to reduce caloric content while also providing sweetness [18]. Therefore, adding Sukkari date powder to biscuits results in a product that is rich in protein, fiber, and minerals (ash), while being lower in carbohydrates and calories. This can be utilized in production of health-enhanced products suitable for children, elderly, and health-conscious individuals such as athletes.

3.1.1.8. Total Phenolic Content of Biscuit Samples Containing Different Levels of Sukkari Date Powder

Figure 1 shows the effect of replacing sugar with Sukkari date powder on the total phenolic content of the biscuits. The results indicate that there were no significant differences between the four treatments in terms of total phenolic content. Some studies have reported that dates are an excellent source of phenolic compounds, which possess very high antioxidant activity [6-22]. The data in this Fig. align with previous studies, which suggest that the total phenolic content in date fruits decreases as the fruit ripens [28-45]. It has also been observed that phenolic content decreases with increasing temperature, and this behavior may be linked to the type of phenolic compound, its sensitivity, and the chemical composition of the food [30].

3.1.1.9. Estimation of Biscuit Physical Properties

1. Estimation of Spreading Ratio

The results in Table (5) show the effect of replacing sugar with Sukkari date powder at different levels on the physical properties (diameter, thickness, and spreading ratio) of the biscuit samples. Regarding the diameter, the results indicated a significant decrease b/w control sample and all biscuit samples with 25%, 50%, and 75% replacement. However, there were no significant differences between the biscuit samples where sugar was replaced with date powder at different levels. A similar trend was observed in the thickness results, the highest thickness found in the control sample (10 mm), while the lowest thickness was in the 75% replacement sample, which recorded a value of 9 mm [10-33]. Regarding the spreading ratio, the results in Table (5) show significant differences between the control sample and the 25%, 50%, and 75% date powder replacement samples. The control sample had the lowest spreading ratio value (4.87%), while the highest value (5.23%) was found at 75% date powder replacement. No significant differences were observed in spreading ratio b/w all date powder replacement samples (25%, 50%, and 75%). This could be attributed to fiber content in dates, which negatively affects cohesion and stability of gluten network [18]. This contrasts with some studies that have indicated a decrease in spreading ratio with higher replacement levels [40-55]. It is worth noting that a higher spreading ratio is considered one of most desirable quality traits in biscuit samples (Ikechukwu et al., 2017).

2. Color Values for Biscuit Samples

The color of Sukkari date powder, which is unsuitable for marketing, was estimated, and the results showed the following values: lightness (L) = 56.58; redness (a) = 5.01, and yellowness (b) = 21.06. The color results for the biscuit samples made by replacing sugar with Sukkari date powder at 25%, 50%, and 75% (Figure 2 & Table 6) showed significant differences in the lightness (L) of the surface between the control sample and the three other samples. The results revealed a decrease in the lightness of

the surface from 62.89 for the control sample to 45.00 for the biscuit sample with 75% date powder replacement. Significant differences were also observed in the redness (a) of the surface between the control sample (7.20) and the 75% date powder replacement sample, which had the highest redness value at 9.03. However, no significant differences were found in the redness values between the three-date powder biscuit samples with the different replacement levels. The decrease in yellowness values (b) attributed to reduction in sucrose content as replacement percentage increased [36].

The results showed significant differences in the yellowness (b) between the control sample and three other samples, with a decrease in yellowness from 25.76 for control sample to 18.31 for 75% date powder replacement sample. Regarding the biscuit base, the results showed significant differences in the lightness (L) between the control sample and all other samples with different date powder replacement levels. The lightness values decreased with higher replacement levels, with values of 64.85, 47.56, 43.19, and 37.99, respectively. The results also showed significant differences in the redness (a) of the base, with the control sample having the lowest redness value (5.17), while the 75% replacement sample had the highest redness value (11.31). Increasing the sucrose replacement with date powder resulted in a darker product with lower lightness values [44]. In terms of yellowness (b) of the base, significant differences were observed between control sample and all three replacement levels. The yellowness decreased from 25.22 for control sample to 16.71 for 75% date powder replacement sample.

3. Hardness Measurement of Biscuit containing different percentages of Sukkari date powder

The results of hardness measurements for biscuit samples with Sukkari date powder replacement at 25%, 50%, and 75% of sugar (Figure 3) showed no significant differences at a 0.05 significance level in hardness among the three replacement levels (25%, 50%, and 75%), with values of 4.72, 4.69, and 4.16 Newton/cm², respectively. However, significant differences were observed between the control sample and the other treatments, with the control sample showing the highest hardness value at 5.78 newton/cm². It is notable that the hardness values decreased as the replacement level of date powder increased. These results agree with a study that indicated an increase in date powder levels lowers the hardness of the resulting biscuits, and that replacing sucrose with date powder has a clear effect on the texture of biscuits [21]. The hardness of biscuits linked to development of gluten and the interaction of date powder with the flour components. A 30% replacement level was found to provide best texture acceptance [36]. Additionally, the increased moisture content in the control sample (4.26%) compared to 75% Sukkari date powder replacement sample (6.68%) certainly affects softness and reduces hardness of the biscuits.

4. Water Activity of Biscuit Samples with Sukkari Date Powder

Water activity is a commonly used term in food science due to its importance in estimating the shelf life of consumer goods [51]. Figure (4) illustrates effect of replacing sugar with non-marketable Sukkari date powder on water activity of resulting biscuits. Results showed no significant difference between control sample and sample with 25% Sukkari date powder replacement. However, significant Z observed between the three treatments with Sukkari date powder replacement levels of 25%, 50%, and 75%, with values of 0.42, 0.47, and 0.50, respectively. The results also showed significant differences between the control sample and the samples with 50% and 75% Sukkari date powder replacement, where the water activity values were 0.47 and 0.50, respectively. An increase in water activity was observed with higher levels of date powder replacement [22]. Water activity value at 25% replacement level was closest to that of control sample, indicating better quality, stability, and longer shelf life during storage compared to other biscuit samples.

3.1.1.10. Sensory Evaluation of Biscuit Samples Containing Different Levels of Sukkari Date Powder

A sensory evaluation was conducted on biscuit samples containing Sukkari date powder, with different sugar replacement levels of 25%, 50%, and 75%. The sensory attributes assessed included appearance, surface color, internal color, texture, taste, and aroma, which collectively contribute to the overall acceptability of the product. The sensory evaluation results, as shown in Table (7), revealed significant differences in appearance, aroma, surface color, and internal color between the control sample and the sample with 75% Sukkari date powder replacement. Specifically, the appearance scores were 19.70 and 18.55, aroma scores were 14.80 and 14.35, surface color scores were 14.55 and 13.95, and internal color scores were 14.45 and 13.45 for the control and 75% replacement, respectively. This indicates a decrease in consumer acceptance due to the darker color of the biscuits as the replacement level increased, which aligns with results from the color attributes (L, a, b) presented in Table (6).The results also showed significant differences in texture, with the control sample scoring 14.95, the 50% replacement scoring 14.15, and the 75% replacement scoring 13.65. There were also significant differences between the 25% and 75% replacement samples (13.65 and 14.50 respectively), suggesting a lower consumer acceptance due to the increase in the biscuit's brittleness, as previously noted with the higher specific volume and lower firmness as replacement increased.

Taste scores for the 25% and 75% replacement samples were 18.40 and 16.70, respectively, indicating substantial variations. In terms of general acceptability, the results indicated that there were no significant differences between the control sample and the 25% or 50% replacement samples, however there were significant disparities between the control sample and 75% replacement. The acceptability score of the control sample was the highest at 97.15, and it gradually decreased when the replacement levels increased to 25% and 50%, scoring 94.90 and 93.80, respectively. The sample with 75% Sukkari date powder replacement had the lowest overall acceptability score (91.40). Previous studies found that the optimal replacement level of date powder in biscuit formulations should not be less than 20% and should not exceed 40%, as these levels were most acceptable to panelists [33]. Another study also showed that biscuits with 30% sugar replacement with date powder scored higher in sensory attributes and were closer to control sample compared to those with 20% or 50% replacement [43].

3.2. Discussion

Effect of replacing sugar with Sukkari date powder on rheological properties of biscuit dough reveals several significant trends that align with previous studies in field.

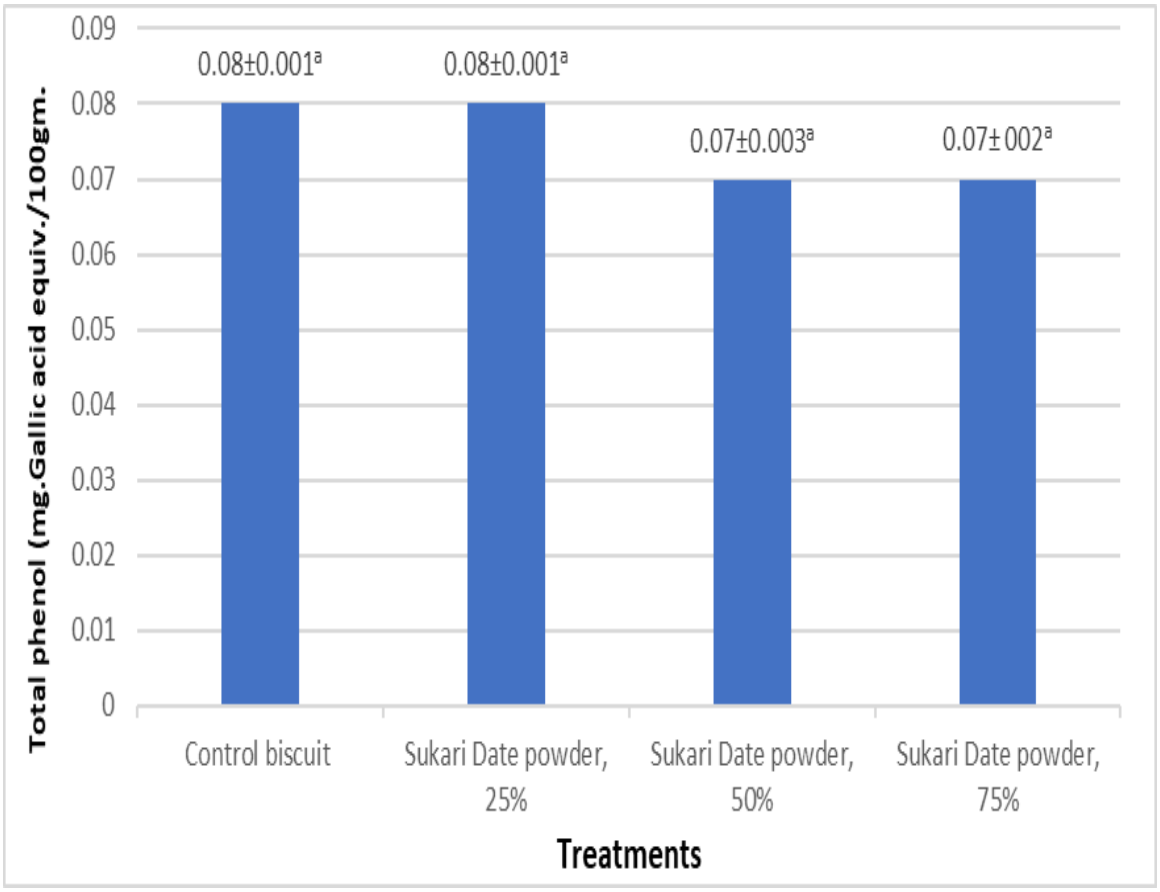

Figure 1. Total phenols of biscuits incorporating Sukkari date powder.

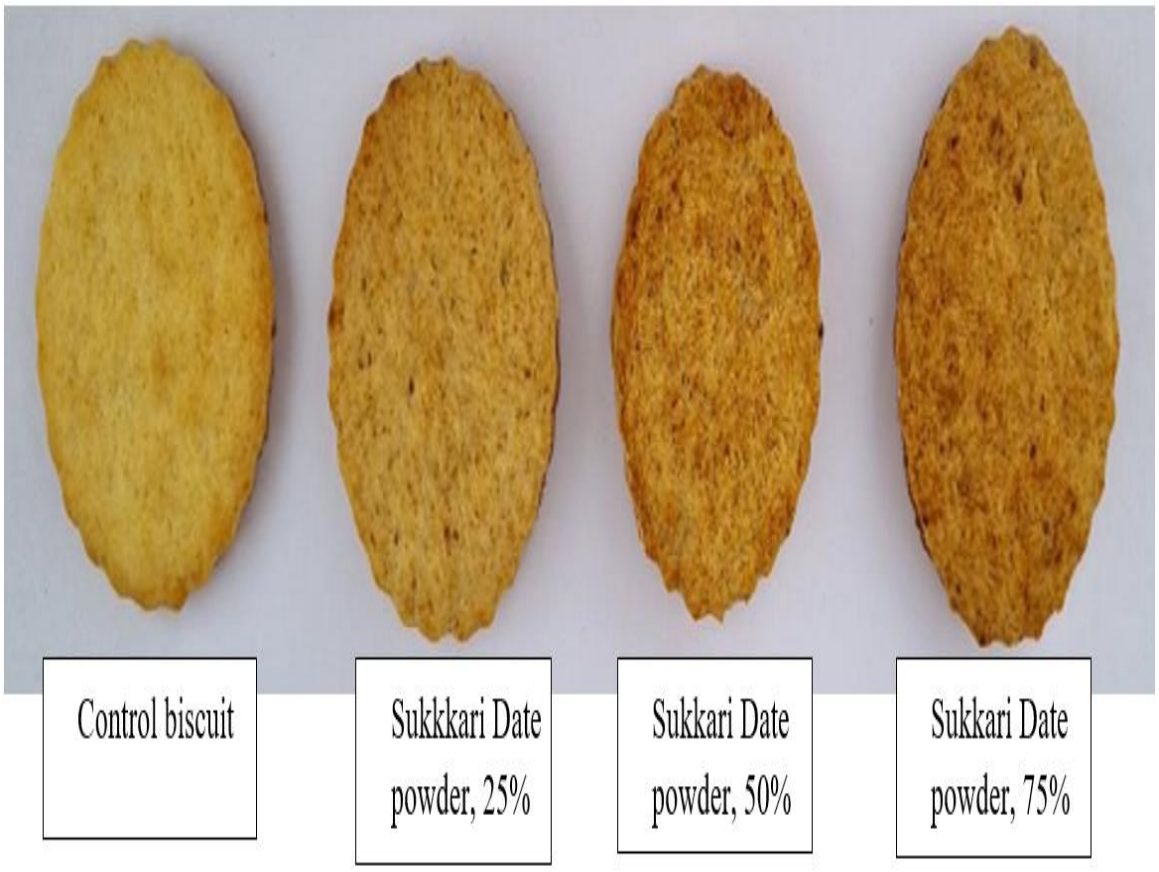

Figure 2. Biscuit samples containing different percentages of Sukkari date powder.

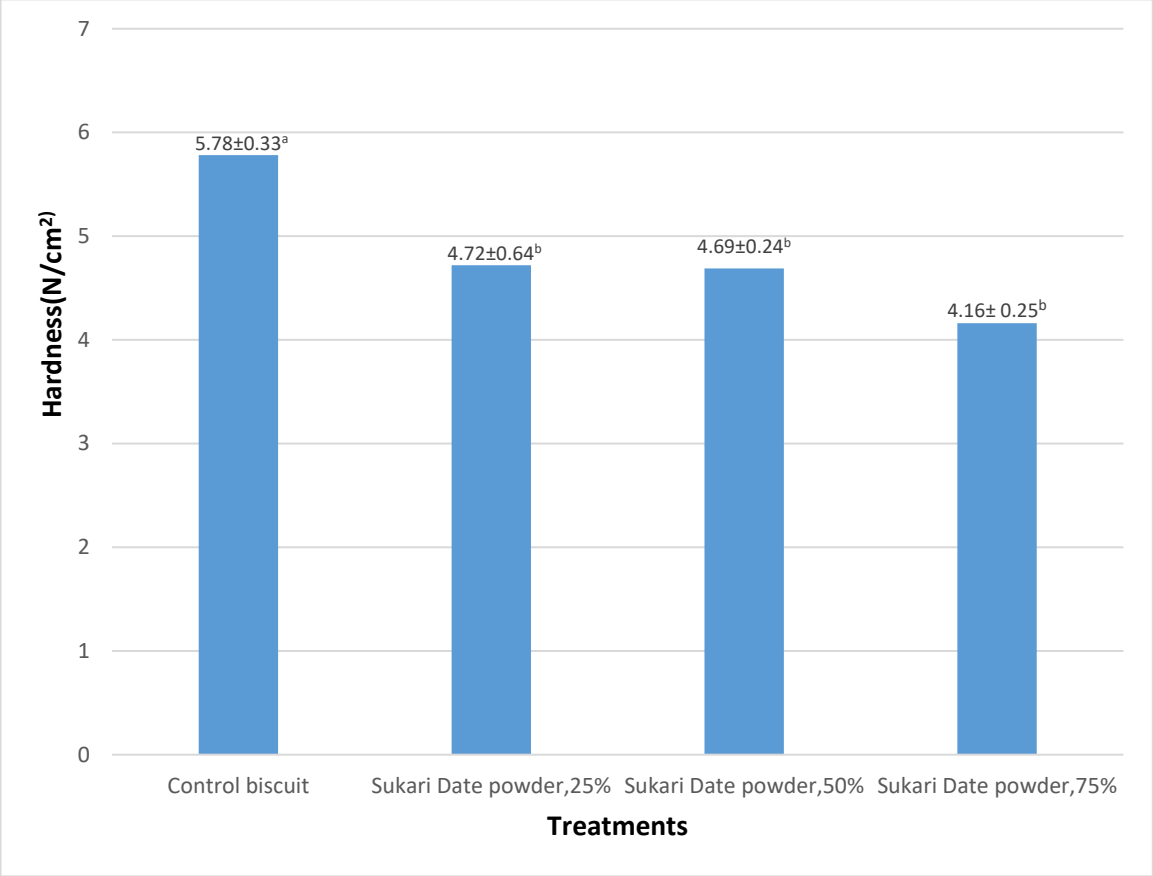

Figure 3. The effect of replacing sugar with Sukkari date powder on the hardness of biscuits

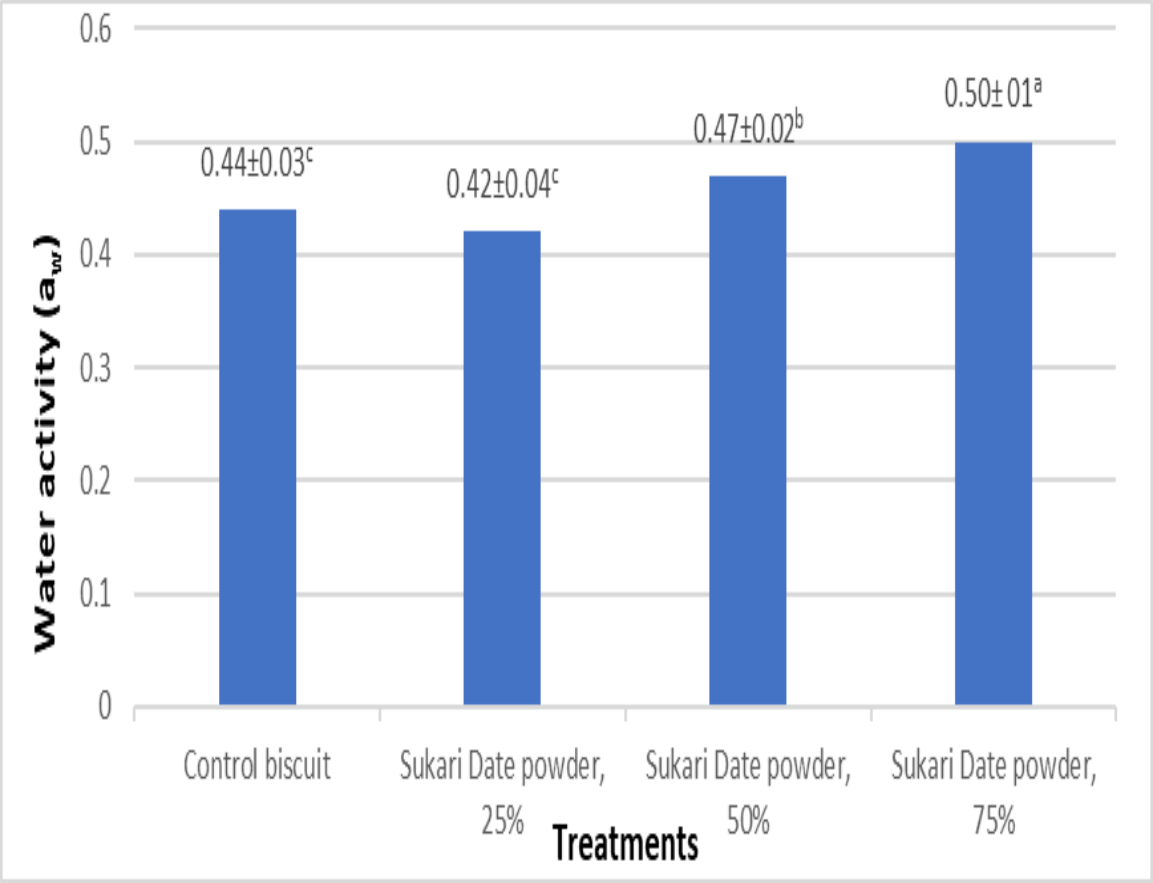

Figure 4. Water activity of biscuits replacing sugar with Sukkari date powder.

Table 1. Ingredients used in preparing biscuit samples, replacing sugar with different percentages of Sukkari date powder.

The components	Control Sample	Percentage of replacing sugar with Sukkari date powder, %		
		25%	50%	75%
Wheat flour	100	95	90	85
Sukkari Date powder	-	7.5	15	22.5
Sugar	30	22.5	15	7.5
Shortening	20	20	20	20
Butter	20	20	20	20
Ammonium bicarbonate	1.5	1.5	1.5	1.5
Sodium bicarbonate	0.4	0.4	0.4	0.4
Vanilla	1	1	1	1
Milk powder	2	2	2	2
Water (according to Farinograph analysis)	65%	64%	66%	67.7%

Table 2. The effect of replacing sugar with Sukkari Date powder on the rheological properties of biscuit dough.

Treatments	Water absorption (%)	Dough development time (Min)	Stability time (Min)	Tolerance index (B.U)	Farinograph Quality number
Control Sample	65.0	2.13	13.28	16	141
Sukkari Date powder, 25%	60.0	5.33	6.13	71	81
Sukkari Date powder, 50%	55.1	5.32	5.56	91	79
Sukkari Date powder, 75%	51.1	6.38	4.58	109	79

Data are mean ± standard error, number of replicates = 3
Data followed by the same letter within the same column have no significant difference (P≤0.05)

Table 3. The effect of replacing sugar with Sukkari date powder on the content of reducing sugars, non-reducing sugars and total sugars (g/100 g of dry weight).

Treatments	Reducing sugars	Non-reducing sugars	Total sugars
Control biscuit	ND	15.84 ± 0.14^{a}	15.84 ± 0.14^{a}
Sukkari Date powder, 25%	0.79 ± 0.15^{c}	14.80 ± 0.32^{b}	15.59 ± 0.27^{a}
Sukkari Date powder, 50%	1.58 ± 0.12^{b}	12.56 ± 0.13^{c}	14.14 ± 0.25^{b}
Sukkari Date powder, 75%	2.37 ± 0.00^{a}	10.32 ± 0.01^{d}	12.69 ± 0.01^{c}

Data are mean ± standard error, number of replicates = 3 ND = not detected
Data followed by the same letter within the same column have no significant difference (P≤0.05)

Table 4. The chemical composition and calories of Sukkari date powder and biscuits (dry basis).

Treatments	Moister Content	Crude Protein	Ash	Fat	Dietary Fiber	Carbohydrates	Calories (kcal/100g)
Control biscuit	4.26 ± 0.69^{b}	6.53 ± 0.0^{d}	1.22 ± 0.40^{b}	21.41 ± 0.29^{a}	2.32 ± 0.03^{d}	68.52 ± 0.62^{a}	492.89 ± 0.25^{a}
Sukkari Date powder, 25%	4.26 ± 0.46^{b}	7.07 ± 0.02^{c}	$1.5\pm0.03a^{b}$	20.99 ± 0.03^{b}	3.25 ± 0.12^{c}	67.19 ± 0.10^{b}	485.93 ± 0.75^{b}
Sukkari Date powder, 50%	5.63 ± 0.01^{b}	7.31 ± 0.04^{b}	1.65 ± 0.02^{ab}	20.58 ± 0.13^{c}	3.63 ± 0.12^{b}	$66.83\pm0.16b^{c}$	481.80 ± 1.04^{c}
Sukkari Date powder, 75%	6.69 ± 0.44^{a}	7.58 ± 0.08^{a}	1.88 ± 0.11^{a}	20.18 ± 0.04^{d}	4.03 ± 0.08^{a}	66.33 ± 0.01^{c}	477.27 ± 0.1^{d}

Data are mean ± standard error, number of replicates = 3
Data followed by the same letter within the same column have no significant difference (P≤0.05)

Table 5. The Effect of Substituting sugar with Sukkari date powder on the Physical Characteristics of the Resulting Biscuits.

Treatments	Diameter W (mm)	Thickness T (mm)	Spread ratio (W/T)
Control biscuit	50.01±1.29[a]	10.00±0.00[a]	4.87±0.40[b]
Sukkari Date powder, 25%	47.68±0.88 [b]	9.17±0.00[b]	5.20±0.04[a]
Sukkari Date powder, 50%	47.75±0.42[b]	9.17±0.00[b]	5.21±0.04[a]
Sukkari Date powder, 75%	47.08±0.74[b]	9.00±0.00[c]	5.23±0.08[a]

Data are mean ± standard error, number of replicates = 3
Data followed by the same letter within the same column have no significant difference (P≤0.05).

Table 6. The Effect of Substituting sugar with Sukkari date powder on the L, a and b Color of the Resulting Biscuits.

	The biscuit surface			The biscuit base		
Treatments	Lightness value (L)	Redness value (a)	Yellowness value (b)	Lightness value (L)	Redness value (a)	Yellowness value (b)
Control biscuit	62.89±2.7[a]	7.20±1.2[b]	25.76±0.3[a]	64.85±2.2[b]	5.17±1.6[b]	25.22±0.8[a]
Sukkari Date powder, 25%	56.79±0.9[b]	8.12±1.2a[b]	20.90±0.8[b]	47.56±3.5[a]	9.49±1.5[a]	19.99±0.6[b]
Sukkari Date powder, 50%	52.07±3.7[b]	8.43±0.6a[b]	20.91±0.1[b]	43.19±2.7a[c]	10.76±0.5[a]	18.87±1.1[b]
Sukkari Date powder, 75%	45.00±0.7[c]	9.03±0.2[a]	18.31±0.1[c]	37.99±0.5[c]	11.31±0.3[a]	16.71±0.1[c]

Estimation of the Resulting Biscuits Surface and Base. Data are mean ± standard error, number of replicates = 3
Data followed by the same letter within the same column have no significant difference (P≤0.05).

Table 7. The Effect of Substituting sugar with Sukkari date powder on the Sensory Properties of the Resulting Biscuits.

Treatments	Appearance (20)	Surface color (15)	Internal color (15)	Texture (15)	Taste (20)	Aroma (15)	Overall acceptability (100)
Control Sample	19.70±0.8a	14.55±1.3a	14.45±1.3a	14.95±0.2a	18.70±2.43a	14.80±0.62a	97.15±4.9a
Sukkari Date powder, 25%	19.05±1.5ab	14.15±1.0ab	13.70±1.4ab	14.50±1.0ab	18.40±2.2a	14.55±0.8ab	94.90±5.8a
Sukkari Date powder, 50%	19.05±1.4ab	14.15±0.8ab	13.65±1.3ab	14.15±1.4bc	18.00±2.5ab	14.50±0.8ab	93.80±5.5ab
Sukkari Date powder, 75%	18.55±1.8b	13.95±1.2b	13.45±1.4b	13.65±1.4c	16.70±3.0b	14.35±1.0b	91.40±6.9b

Data are mean ± standard error, number of replicates = 10
Data followed by the same letter within the same column have no significant difference (P≤0.05).

Water Absorption: As the percentage of Sukkari date powder increased, the water absorption of the biscuit dough decreased. This result is consistent with a study by [43], which observed a similar reduction in water absorption when date powder was used as a sugar substitute. The reduction in water absorption is attributed to the high level of reducing sugars, particularly fructose, in date powder. These sugars create a sticky mass that aids in hydration, unlike the control dough which required more water to hydrate the starch and protein components in the flour.

Dough Development Time: The time required for dough development increased with higher levels of date powder replacement. The control sample required the shortest time, while the 75% replacement sample took the longest. This trend can be attributed to the fiber content and the coarse particles of date powder, which require more time to properly incorporate into the dough, as also observed by [43]. This aligns with findings from other studies such as [21], which reported increased dough development time when higher levels of wheat bran and date powder were used.

Dough Stability and Tolerance Index: Dough stability decreased with increasing replacement levels of date powder, which was observed in the reduction of stability time from 13.28 minutes in the control sample to 4.58 minutes in the 75% replacement sample. This suggests that the presence of date powder fibers negatively affected the gluten network in the dough. Additionally, the tolerance index increased as more date powder was incorporated, indicating a reduced resistance to mixing. Similar findings were noted in a study by [48], which also reported that higher levels of date powder weakened the dough's ability to withstand mixing.

Farinograph Quality Number: The quality number of the dough decreased with increasing date powder substitution, from 141 in the control sample to 79 in the 75% replacement sample. This trend reflects the cumulative impact of the fibers, sugars, and other components of date powder on the dough's overall quality, corroborating the results from studies on other sugar substitutes like date palm powder [4].

Sugar Content and Chemical Composition: As expected, replacing sugar with Sukkari date powder led to a significant

increase in reducing sugars and a decrease in non-reducing sugars. This aligns with findings of [29-30], which noted that dates are rich in reducing sugars, particularly fructose and glucose, which contribute to the sweetness of biscuits. Chemical analysis also revealed an increase in protein, fiber, and ash content with higher date powder substitution, suggesting a more nutritious product. These findings are consistent with other studies that highlighted nutritional benefits of date powder in bakery products [33-50].

Physical Properties and Sensory Evaluation: The physical properties, such as spreading ratio and hardness, showed a clear trend with increasing substitution levels. A higher spreading ratio was observed in biscuits with more date powder, which could be attributed to the effect of fiber on the dough's cohesion and stability, as noted in [20]. The decrease in hardness with increased date powder replacement suggests that the biscuits became softer, which is in line with previous studies indicating that higher moisture content and the textural effects of date powder contribute to softer textures in baked goods [21]. In conclusion, the incorporation of Sukkari date powder as a sugar substitute not only impacts rheological properties of biscuit dough but also enhances its nutritional profile. These findings highlight the potential of using date powder in bakery products to create healthier alternatives with improved fiber, protein, and mineral content, while also altering texture and sensory characteristics of the biscuits.

4. Conclusions

Considering that sensory evaluation is the final determinant in consumer acceptance or rejection of a food product, regardless of its chemical composition, and based on the results obtained in this study, it can be recommended that non-marketable dates, such as "dry Sukkari dates," be converted into powder to replace sugar. This powder is rich in fibers, antioxidants, & other health-enhancing compounds, making it an excellent addition to baked goods, particularly biscuits and replacement ratio could be up to 50% powdered low-quality Sukkari. Rheological properties of biscuit dough show that stability value decreased with higher replacement levels, reaching 4.58 minutes at 75% replacement. This decrease is attributed to impact of date powder fibers on gluten network in dough. While dough development time need for more time with increasing replacement. Reducing sugars increase with higher substitution levels and no significant differences observed in spreading ratio between all date powder replacements samples also, no significant differences b/w four treatments of total phenolic content. Hardness measurements for biscuit samples with Sukkari date powder replacement of sugar showed no significant differences at 0.05. The water activity (aw) for all biscuit samples recorded values less than 0.60 makes biscuits stability during storage.

Future studies could focus on exploring the environmental benefits of utilizing non-marketable dates in the food industry, particularly in terms of reducing waste and minimizing environmental impact. Additionally, research could investigate how converting these dates into food products can enhance agricultural productivity in the Qassim region, creating new economic opportunities for farmers while also addressing sustainability challenges. Such studies would contribute to improving resource efficiency and support the development of sustainable agricultural practices within the region.

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