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Rheological, Physicochemical, and Organoleptic Properties of High-Fiber Biscuits Incorporated with Unpollinated Barhi Date Fruit Powder

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Abstract

This research aims to utilize Unpollinated Barhi Date Fruit Powder (UBDFP) harvested at the Khalal maturity stage for creating functional biscuits that are high in fiber content and cost-effective. This involves substituting wheat flour with varying proportions of UBDFP, specifically 5%, 10%, and 15%, and investigating its impact on the rheological characteristics of the biscuit dough as well as the physical, chemical, and sensory attributes of the final biscuits. The results showed a clear effect on the rheological properties of the biscuit dough, with an increase in the water absorption ratio of the flour and dough development time, and a decrease in its stability time with an increase in the replacement ratios due to the high fiber content in the UBDFP and its low gluten content. The highest protein content was recorded in the control biscuit at 6.53%, and the lowest in the sample of UBDFP at 15%, which was 6.22%. The results also showed an increase in the reducing sugars to 1.57% at a replacement ratio of 15% of UBDFP, with no significant differences in ash content between the control sample at 1.22% and both replacement samples of UBDFP at 5 and 10%, which were 1.41 and 1.67%, respectively. The highest ash content was found at a replacement ratio of 15% of UBDFP at 1.77%. There were significant differences in fiber content between the control sample and each of the other three treatments, where the fiber content increased from 2.32% in the control sample to 4.14% for the sample of UBDFP at 15%. There were no significant differences between all treatments and the control in the content of total phenolic compounds, with values ranging from 8 to 9 milligrams gallic acid equivalent per 100 g. of dry sample, Based on the results of sensory evaluation, which is the final decision factor for consumers to accept or reject a food product. Therefor, it can be recommended to convert non-marketable Barhi dates, including " Unpollinated " ones, into powder added as a fiber-enriched, antioxidant, and health-enhancing due to their phytochemicals and low fat content, potentially reducing cholesterol, heart disease, and cancer risks, attributed to their dietary fiber content which aids in stomach function and cholesterol reduction and substance in biscuit production at a ratio of up to 10% to maximize its utilization.

Keywords: nutrition; Attitude to health, dietary fiber, High fiber, functional foods and biscuits.

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1. Introduction

Biscuits and cookies are widely consumed snacks, particularly among children, due to their appealing flavors and textures. They offer the convenience of a long shelf life due to low moisture content, but their high-fat content and reliance on refined wheat flour result in limited nutritional value. Wheat flour is low in fiber and essential minerals, which has driven interest in enhancing biscuits' nutritional profiles by incorporating nutrient-rich alternatives. Fruit and vegetable by-products, which are abundant in fiber, minerals, and antioxidants, have shown promise in improving the functional properties of baked goods [1]. Date palm holds immense agricultural significance in Saudi Arabia, contributing to 75% of the nation's total fruit production [2]. Between 2018 and 2019, Saudi Arabia ranked as the second-largest global producer of dates, with an output of 1,483,631 tons [3]. The Al-Qassim region is a major contributor, producing approximately 205,000 tons annually from its eight million date trees, with plans to double production by 2030 [4]. Dates are celebrated for their nutritional and health benefits, including high dietary fiber content, antioxidants, and phytochemicals that may reduce risks of cholesterol, heart disease, and cancer, while improving digestion [5]. Date fruit ripens through distinct stages, from kimri to tamr, with the Khalal stage offering a unique nutritional profile.

Unlike most varieties, Barhi dates are palatable at the Khalal stage due to their sweetness, crunchiness, and tannin-free nature, making them highly marketable. However, unpollinated fruits pose a challenge, as they are typically discarded, leading to significant economic losses for farmers. Research estimates that 20-30% of date production is lost annually due to unpollinated fruits and overproduction [6]. Despite this, unpollinated Barhi dates are rich in fiber and plant compounds, offering the untapped potential for functional food production and environmental sustainability. Discarded fruits and plant residues, however, offer valuable dietary fiber and plant chemicals, contributing to environmental sustainability. Dates, renowned for their nutritional and economic value, boast high dietary fiber content, ranging from 6.5-11.5%, with significant health benefits including cardiovascular disease prevention [7]. Additionally, date fibers enhance food processing properties such as water and oil retention, making them versatile ingredients in various food products like dairy, meat, and bakery items, thus highlighting their potential for value-added applications [8-9].

Dietary fiber from dates has proven benefits, including reducing the risk of cardiovascular diseases, managing cholesterol and glucose levels, and alleviating digestive disorders. Additionally, fiber-rich foods enhance food processing properties, such as water retention and emulsification, making them versatile in applications ranging from bakery items to soups [10]. However, excessive incorporation of dates in food products can lead to sensory challenges, such as increased hardness and darker coloration, which necessitates careful optimization in functional biscuit production [11]. This study presents a novel approach to utilizing Unpollinated Barhi Date Fruit Powder (UBDFP) at the Khalal stage to develop cost-effective, fiber-rich biscuits by replacing wheat flour with varying levels of UBDFP. Conducted at Qassim University in 2023, the research investigates the rheological properties of biscuit dough and the quality attributes of the resultant biscuits to identify the optimal replacement ratio. This study's novelty lies in repurposing unpollinated Barhi dates, a low-value by-product, to create functional biscuits with enhanced nutritional and medical benefits, addressing health concerns such as cholesterol reduction and improved digestion while promoting sustainable food practices.

2. Materials and Methods

2.1. Materials

The biscuit samples were prepared using the following ingredients: 70% extraction wheat flour, sugar, shortening, skimmed milk powder, butter, vanilla, sodium chloride, ammonium bicarbonate, and sodium bicarbonate, all sourced from local markets in the Qassim region, Saudi Arabia. UBDFP, harvested at the Khalal stage, was obtained from a Barhi palm farm in the same region. High-purity chemicals required for the study were procured from Sigma Company, Riyadh, and KSA.

2.2. Methods

2.2.1. Preparation of UBDFP

UBDFP was prepared at the Khalal maturity stage using the method described by Abd El-Hady et al. (2022) [12]. The unpollinated fruits were dried in a hot-air dryer at 70°C for 12 hours, then milled using a laboratory mill (Model 3100, Perten Instruments, Sweden) to produce UBDFP. The powder was packed into polyethylene bags and stored at 7 ± 2°C until use.

2.2.2. Rheological Analysis of Biscuit Dough

The rheological characteristics of biscuit dough were evaluated by substituting wheat flour (70% extraction) with UBDFP at replacement levels of 0%, 5%, 10%, and 15%. The parameters analyzed included water absorption percentage, dough development time, stability, tolerance index, and Farinograph quality number. Measurements were conducted using a Farinograph apparatus (Type 810107, Brabender OHG, and Duisburg, Germany).

2.2.3. Biscuit Preparation

Biscuit samples were prepared according to the method described by Leelavathi and Haridas Rao (1993), with modifications. Sugar, fat, and vanilla were creamed using a kitchen mixer (Kenwood HM 1010, Beijing, China) at medium speed (125 rpm) for 6 minutes to achieve a creamy consistency. Sifted flour, mixed with sodium bicarbonate, ammonium bicarbonate, milk powder, and salt, was gradually incorporated into the mixture and mixed for another 4 minutes at 61 rpm. Water was added based on Farinograph analysis to achieve the desired dough consistency (Table 1). The dough was rolled out to a thickness of 0.5 cm using a wooden rolling pin on a flat wooden board and cut into circular shapes (5.5 cm diameter) with a cutter. The biscuits were baked in a hot-air electric oven at 180 ± 4°C for 15 minutes. After baking, they cooled to room temperature and stored in tightly sealed polyethene bags until further analysis.

2.2.4. Proximate Analysis

The proximate analysis of wheat flour, UBDFP, and prepared biscuit samples included the determination of moisture, ash, crude protein, lipids, crude fiber, quantitative sugars, and caloric content.

2.2.5. Total Phenolic Content

Total phenolic content was measured using the Folin–Ciocalteu method as described by Singleton et al. (1999). Half a gram of each biscuit sample (control and those containing 5%, 10%, and 15% UBDFP) was mixed with 20 ml of methanol: water (70:30), centrifuged and diluted to 25 ml. A portion of the solution was used to measure the blue color formed at 750 nm using a UV/VIS 1201 spectrophotometer (Shimadzu, Kyoto, Japan). A standard curve of gallic acid was used for comparison, and the results expressed as mg gallic acid equivalent (GAE)/g of sample.

2.2.6. Water Activity

Water activity (WA) in the biscuit samples was measured using an Aqua Lab water activity analyzer (Decagon Devices Inc., Pullman, WA, USA).

2.2.7. Color and Physical Measurement

Instrumental color measurements, including lightness (L*), redness (a*), and yellowness (b*), were recorded using the Hunter Lab color measurement system

(Hunter Lab, Color Flex, Hunter Associates Laboratory, USA) following the method by Al-Juhaimi et al. (2016) [13]. The physical dimensions of the biscuits, including diameter (W) and thickness (T), were measured in millimeters.

2.2.8. Biscuit Hardness

Biscuit hardness was analyzed using an HD Plus Texture Analyzer (Stable Micro Systems, Godalming, UK) equipped with a 25.0 kg weight and a sharp cutting knife (HDP/BS). Test settings included a pre-test speed of 1.5 mm/s, test speed of 0.5 mm/s, post-test speed of 10.0 mm/s, a cutting distance of 5 mm, and a tool force of 25 g. Hardness was defined as the maximum force (N) and distance (mm) required to break the biscuit [14].

2.2.9. Sensory Evaluation

A panel of 10 faculty members from the Food Science and Human Nutrition Department at Qassim University assessed sensory attributes of biscuits. Parameters such as appearance, surface color, interior color, texture, taste, aroma, & overall acceptability evaluated in comparison to the control sample. The sensory evaluation was conducted following the procedure outlined by Khalil et al. (2023) [15].

2.2.10. Statistical Analysis

Statistical analysis was performed on all results using analysis of variance (ANOVA). Three replicates were used for most analyses, except for biscuit hardness, where six replicates were tested, and sensory evaluation, which included ten replicates. Differences among treatments were determined using Duncan's Multiple Range Test at a significance level of $P \leq 0.05$ with computations performed using SAS software.

3. Results and discussion

The Farinograph analysis of biscuit dough with various UBDFP substitution levels (5%, 10%, and 15%) revealed notable changes in rheological properties (Table 2). The incorporation of UBDFP at various substitution levels significantly influenced the rheological properties of the biscuit dough. Water absorption increased progressively with higher UBDFP levels, reaching 64.3%, 66.0%, and 67.7% for substitution ratios of 5%, 10%, and 15%, respectively, compared to 65.0% in the control. This increase is attributable to the high water-binding capacity of dietary fibers in UBDFP. Dough development time also showed a proportional increase with rising UBDFP levels, recording 5.58 minutes at 5% substitution, 7.03 minutes at 10%, and 9.44 minutes at 15%, compared to the shortest time of 2.13 minutes in the control. This reflects the delayed hydration of dough caused by fiber incorporation. Conversely, dough stability decreased as the substitution ratio increased, with the control sample exhibiting the highest stability at 13.28 minutes, while the 15% UBDFP sample recorded the lowest stability at 9.41 minutes. Analysis of mixing resistance index revealed an upward trend with higher substitution levels. The control dough recorded lowest value at 16 Brabender units, whereas 5% and 15% substitution samples reached highest values at 46 Brabender units.

This suggests that UBDFP incorporation increases dough resistance but may reduce its tolerance during mixing. The Farinograph quality number (FQN), a comprehensive measure of dough quality, decreased with rising UBDFP levels. The control dough recorded the highest FQN at 141, while the values for 5%, 10%, and 15% UBDFP substitution samples were 134, 111, and 116, respectively. This decline indicates that higher dietary fiber levels impact dough quality, highlighting the need for optimized substitution ratios to balance nutritional enhancement with acceptable processing properties (Table 2). The findings highlight that incorporating UBDFP into biscuit dough significantly alters its rheological properties, primarily due to its high fiber content. Increased water absorption percentages align with prior research showing the hydrophilic nature of dietary fibers, which bind water through hydrogen bonding [16]. This enhanced water-binding capacity improves dough hydration, contributing to extended shelf life by lowering WA. However, higher substitution levels prolong dough development time as dietary fibers interact with gluten proteins, delaying hydration and weakening gluten structure, which reduces dough stability and Farinograph quality [17].

Despite these effects, dietary fibers provide substantial health benefits, such as aiding digestion, improving bowel regularity, supporting gut micro biota, lowering cholesterol, and reducing blood glucose spikes, contributing to cardiovascular health [7]. Optimizing UBDFP substitution levels (e.g., 5–10%) ensures improved nutritional value without compromising product quality. Excessive substitution may result in undesirable changes, such as tougher textures or darker coloration, which can affect consumer acceptance. Leveraging unpollinated Barhi date fruits, typically discarded as by-products, offers an innovative way to reduce food waste and create fiber-rich, functional food products. The quantitative evaluation of sugars in UBDFP and biscuit samples showed that UBDFP contains 25.18 g of total sugars, 12.69 g of non-reduced sugars, and 37.87 g of reduced sugars per 100 g of dry weight (un-tabulated data). When wheat flour was substituted with UBDFP, there was a significant increase in the content of reduced sugars across all treatments (5%, 10%, and 15%).

The reduced sugar content was 0.53%, 1.05%, and 1.57% for these samples, respectively. In comparison, the total sugar content of the control sample did not significantly differ from the 5% replacement sample, but it did increase with higher UBDFP substitution, reaching values of 16.02%, 16.60%, and 17.67% for the 5%, 10%, and 15% treatments, respectively (Table 3). The inclusion of UBDFP increases reducing sugar levels in biscuits, due to natural conversion of sucrose to glucose & fructose as Barhi dates ripen—a process facilitated by invertase enzyme. This results in biscuits with higher total sugar content, enhancing their natural sweetness without added sugars or artificial sweeteners [18]. The health benefits of Barhi dates, rich in antioxidants, fiber, & essential minerals, contribute to improved digestion, blood sugar regulation, and weight management. Increased fiber supports satiety and may aid in reducing obesity risks. The presence of reducing sugars also enhances antioxidant properties, potentially mitigating oxidative stress and related conditions like cardiovascular disease and diabetes. By replacing refined sugars with natural sugars from UBDFP, these biscuits offer a health-conscious option with added nutritional value. The chemical composition of UBDFP during the khalal stage and wheat flour analyzed and compared. The moisture content of UBDFP and wheat flour were 6.49% & 11.27%, respectively.

The protein, ash, and fat contents were 0.33%-10.90%, 3.79%-1.37%, and 0.33%-1.80%, respectively. The fiber and carbohydrate contents were 15.57%-0.5% and

79.98%-85.43%, respectively, on a dry basis (un-tabulated data). The impact of substituting wheat flour with UBDFP on the chemical composition of biscuits is presented in Table 4. Moisture content showed no significant differences between the control sample and all biscuit samples with UBDFP (5%, 10%, and 15%). However, significant differences in protein content were observed, with the highest value found in the control sample (6.53%) and lowest in the 15% substitution sample (6.22%). Ash content remained consistent across the control (1.22%) and the 5% and 10% substitution samples (1.41% and 1.67%, respectively), with the highest value in the 15% substitution sample (1.77%). Fat content significantly increased from 21.41% in the control to 24.02% in 15% substitution sample. Fiber content showed significant differences, with the control sample containing 2.32% fiber, and 15% UBDFP substitution sample containing 4.14%. Carbohydrate content decreased with increasing substitution of UBDFP, with the 15% substitution sample having the lowest carbohydrate value (63.85%) compared to the control sample (68.52%).

The caloric content varied significantly between treatments, with the 15% UBDFP substitution sample showing the highest caloric value of 496.47 calories/100 g. Nutritional analysis reveals significant benefits of UBDFP, particularly in terms of dietary fiber, which improves bowel movements, prevents constipation, and reduces colorectal disease risk. Higher ash content in UBDFP-substituted biscuits, attributed to the mineral content of Barhi dates, enhances the mineral profile, supporting bone health with essential nutrients like calcium, magnesium, and potassium. Although protein content slightly decreases with higher UBDFP substitution, it remains comparable to control samples, showing minimal impact. The natural waxy layer on the date fruit may account for the slight increase in fat content at higher substitution levels, aiding energy absorption and utilization of fat-soluble vitamins. Moreover, dried dates with hard, dry kernels contain more sucrose than reducing sugars, potentially contributing to high-energy food products [19]. The reduction in carbohydrate content with higher UBDFP substitution is particularly advantageous for individuals managing blood sugar levels, such as those with diabetes.

Lower carbohydrate biscuits enriched with fiber improve glycemic control, offering a healthier alternative to traditional biscuits. While caloric content increases with higher UBDFP substitution, making these biscuits more energy-dense, this can benefit athletes or individuals requiring weight gain. However, this needs to be balanced with the benefits of increased fiber and reduced sugars [20]. The effect of substituting wheat flour with UBDFP on the total phenolic content of the biscuits was examined and is presented in Figure 1. The results showed no significant differences in the total phenolic content between all treatments and the control biscuit sample, with values ranging from 8 to 9 milligrams gallic acid equivalent per 100 g of dry sample. Although dates harvested at the full khalal stage are rich in antioxidants, particularly phenolic compounds such as tannins, the levels of these compounds gradually decrease as the fruit ripens further. A significant decrease in the phenolic content of Barhi date fruits at the khalal stage was observed after harvesting and storing fruit in unmodified atmospheres. Substituting wheat flour with UBDFP did not significantly affect total phenolic content in biscuits. This may be due to reduced phenolic compounds as dates mature or due to storage and processing conditions.

Although dates are a good source of antioxidants, factors like storage duration and exposure to high temperatures can reduce the availability of phenolic compounds [21]. Phenolic compounds play a key role in protecting the body from oxidative stress, which is linked to chronic diseases such as cardiovascular conditions, diabetes, and neurodegenerative disorders. Foods rich in phenolic compounds can reduce these risks by neutralizing free radicals. However, the observed decrease in phenolic content in biscuits highlights the need to optimize harvesting and processing conditions to maximize antioxidant potential. Despite this reduction, the remaining phenolic compounds still provide moderate antioxidant benefits, supporting overall health and reducing oxidative damage [22]. The physical characteristics of the biscuit samples, including diameter, thickness, and spread ratio, were analyzed and are presented in Table 5. The results showed no significant differences in the diameter of the biscuits between the control sample and samples with UBDFP substitution at 5%, 10%, and 15%. However, notable variations were observed in thickness of biscuits, with control sample exhibiting highest thickness of 10.0 mm. The thickness of biscuits decreased as substitution rate of UBDFP increased, with sample containing 15% UBDFP having a thickness of 8.33 mm.

Regarding the spread ratio, significant differences were found between the control sample and the biscuits with UBDFP substitution. The spread ratio values increased with higher UBDFP substitution rates, suggesting that higher fiber content in the dough contributed to greater biscuit spread. Reduced thickness and increased spread ratio are consistent with the effects of dietary fibers, which weaken gluten networks, making dough more extensible and less cohesive. These changes yield biscuits with a crisp texture, which can be desirable for specific baked goods. Higher fiber content also supports digestive health, regulates intestinal transit, and promotes gut micro biota. Additionally, dietary fibers reduce risk of cardiovascular diseases, type 2 diabetes, and certain cancers, contributing to the functional food category [20]. The color of UBDFP at the khalal mature stage was assessed and showed an increase in the lightness (L) value, reaching 67.82, while the redness (a) value decreased to 3.15, and the yellowness (b) value recorded was 13.92. For the biscuit samples, significant differences were observed in the lightness (L) of the biscuit surface between the control sample and the treatments with UBDFP substitution.

The control sample had a lightness value of 62.89, which decreased to 50.95 for the 15% UBDFP substitution sample. The 10% substitution sample showed a similar decrease, with a lightness value of 52.20, but no significant difference compared to the 15% substitution treatment. As for the redness (a) of the biscuit surface, no significant differences were found among the control sample and the samples with 5%, 10%, and 15% UBDFP substitution. Regarding yellowness (b), significant differences were found, with the control sample having the highest value of 25.76 and the 15% UBDFP substitution sample showing the lowest value at 18.87. For the biscuit base, significant differences were noted in the lightness (L) between the control and the UBDFP substitution treatments. The lightness level of the biscuit base decreased from 64.85 in the control sample to 42.05 in the 15% substitution sample. As for redness (a), the control sample had the lowest value of 5.17, while the substitution treatments recorded higher values, reaching 10.33 at the 15% substitution. Significant differences in yellowness (b) also found b/w control and the substitution treatments, with values decreasing from 25.22 for the control sample to 17.30 for the 15% UBDFP substitution (Table 6).

The hardness of the biscuit samples was evaluated, and the results, as shown in Figure 2, indicated an increase in hardness with higher substitution percentages of UBDFP. A significant difference was observed between 15% UBDFP substitution treatment and the other three treatments. The hardness value increased from 5.78 N/cm² in control sample to 7.54 N/cm² in the 15% UBDFP substitution sample. This increase in hardness directly related to level of substitution, with the highest hardness observed at the 15% UBDFP substitution. These changes are consistent with natural pigments in date fibers and structural reinforcement provided by fiber [23]. Darker color may indicate presence of bioactive compounds, such as phenolic compounds and flavonoids, which have anti-inflammatory, antioxidant, and anti-cancer properties. Increased biscuit hardness may enhance satiety, aiding appetite control [22]. While the darker color might affect sensory attributes, it could appeal to consumers associating it with natural, less processed products.

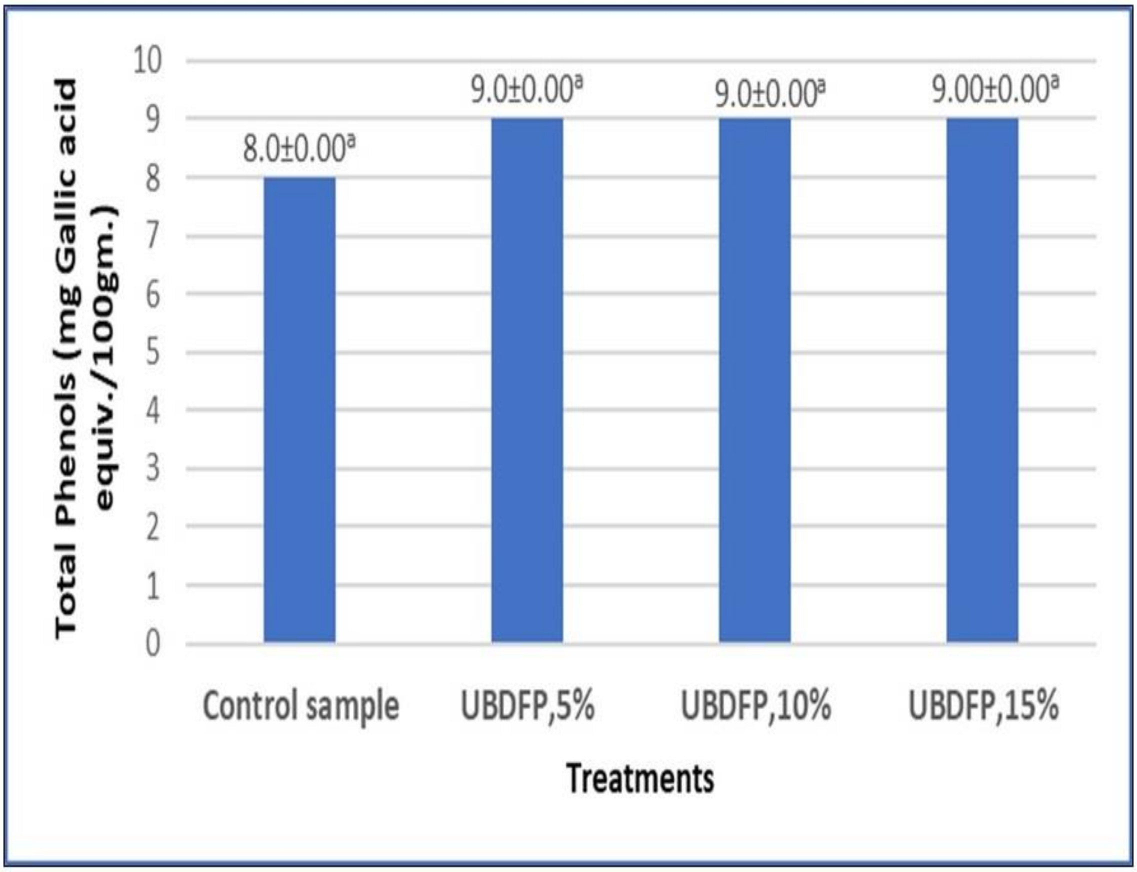

Figure 1: Total phenols of biscuits incorporating UBDFP.

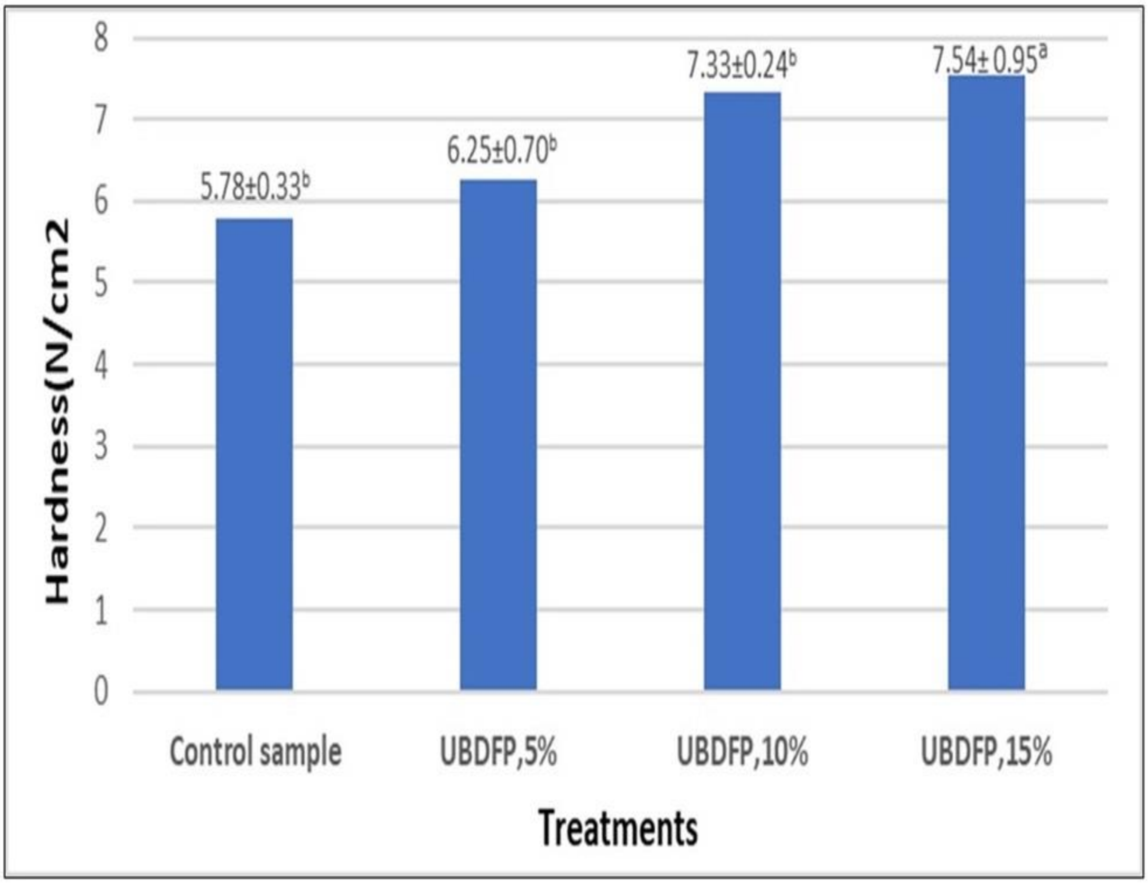

Figure 2. Hardness of biscuits incorporating UBDFP.

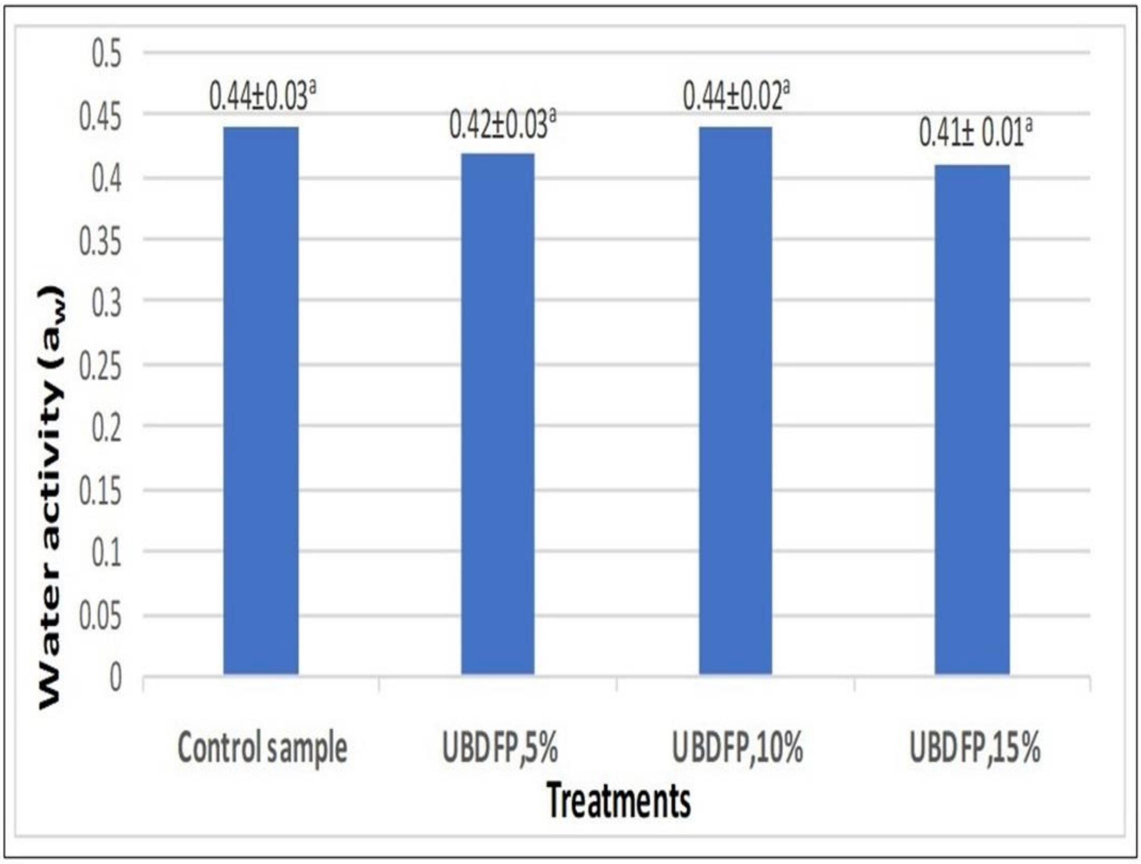

Figure 3. The water activity of biscuits incorporating UBDFP

Figure 4. Resulting Biscuits Containing Different Levels of UBDFP.

Table 1. Ingredients used in the preparation of biscuits supplemented with UBDFP.

Components	Control	UBDFB biscuits		
		5%	10%	15%
Wheat flour	100	95	90	85
UBDFP	-	5	10	15
Sugar	30	30	30	30
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 Substituting Wheat Flour with UBDFP on the Farinograph Properties of Dough Biscuit.

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
UBDFP (5%)	64.3	5.58	11.59	46	134
UBDFP (10%)	66.0	7.03	10.02	41	111
UBDFP (15%)	67.7	9.44	9.41	116	46

Table 3. Reducing, non-reducing, and total sugars (% on dry weight) of biscuits incorporating UBDFP.

Treatments	**Reducing sugars**	**Non-reducing sugars**	**Total sugars**
Control Sample	ND	15.84±0.14^{a}	15.84±0.14^{c}
UBDFP (5%)	0.53±0.13^{c}	15.49±0.34^{a}	16.02±0.47^{c}
UBDFP (10%)	1.05±0.11^{b}	15.55±0.13^{a}	16.60±0.02^{b}
UBDFP (15%)	1.57±0.16^{a}	15.60±0.19^{a}	17.67±0.03^{a}

Data are expressed as mean ± standard error, number of replicates = 3. ND: not detected, Data followed by the same letter within the same column have no significant difference ($P \leq 0.05$).

Table 4. The effect of substituting wheat flour with UBDFP on the chemical composition and calorie content of the resulting biscuits (gm/100 gm of dry weight).

Treatments	Moister content	Crude Protein	Ash	Fat	Dietary Fiber	Carbohydrates	Calories (kcal/100g)
Control Sample	4.26± 0.69^{a}	6.53± 0.01^{a}	1.22 ± 0.40^{b}	21.41± 0.29^{c}	2.32± 0.03^{b}	68.52± 0.62^{a}	492.89± 0.25^{b}
UBDFP (5%)	4.65± 0.07^{a}	6.44± 0.07^{b}	1.41 ±0.11^{ab}	21.72± 0.11^{c}	4.03± 0.03^{a}	65.40± 0.24^{b}	486.83± 0.04^{d}
UBDFP (10%)	4.43± 0.29^{a}	6.28± 0.09^{c}	1.67 ±0.13^{ab}	22.87±0.07^{b}	4.08± 0.12^{a}	64.56± 0.25^{c}	491.37± 0.42^{c}
UBDFP (15%)	3.64± 1.42^{a}	6.22± 0.12^{d}	1.77 ± 0.05^{a}	24.02± 0.07^{a}	4.14± 0.01^{a}	63.85± 0.02^{c}	496.47± 0.12^{a}

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

Table 5. The effect of substituting wheat flour with UBDFP on the physical characteristics of the resulting biscuits.

Treatments	Spread ratio (W/T)	Thickness T (mm)	Diameter W (mm)
Control Sample	50.01±1.29^{a}	10.00±0.00^{a}	4.87±0.40^{d}
UBDFP (5%)	50.08±1.20^{a}	9.83±0.00^{b}	5.10±0.12c
UBDFP (10%)	50.00±0.84^{a}	8.67±0.00c	5.77±0.10^{b}
UBDFP (15%)	50.67±0.61^{a}	8.33±0.00^{d}	6.08±0.07^{a}

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

Table 6: The Effect of Substituting Wheat Flour with UBDFP on the L, a, b Color Estimation of the Resulting Biscuits Surface and Base.

Treatments	The biscuit surface			The biscuit base		
	L	**a**	**b**	**L**	**a**	**b**
Control Sample	62.89± 2.66^{a}	7.20± 1.21^{a}	25.76± 0.27^{a}	64.85± 2.20^{a}	5.17±1.62^{b}	25.22± 0.82^{a}
UBDFP (5%)	58.91± 0.43^{b}	5.85± 0.32^{a}	21.41± 0.15^{b}	51.98± 2.71^{b}	9.32±1.09^{a}	21.39± 0.51^{b}
UBDFP (10%)	52.20± 0.91^{c}	6.86± 1.27^{a}	19.74± 0.99^{c}	45.86± 3.23^{c}	9.50±1.14^{a}	18.59± 0.68^{c}
UBDFP (15%)	50.96± 0.38^{c}	6.67± 1.02^{a}	18.87± 0.69^{c}	42.05± 3.58^{c}	10.33± 0.78^{a}	17.30± 0.99^{c}

Data are expressed as mean ± standard error, number of replicates = 3. Data followed by the same letter within the same column have no significant difference ($P \leq 0.05$). L: Lightness value; a: Redness value; b: Yellowness value.

Table 7. The Effect of Substituting Wheat Flour with UBDFP on the Sensory Properties of the Resulting Biscuits.

Treatments	**Overall acceptability**	**Aroma**	**Taste**	**Texture**	**Internal color**	**Surface color**	**Appearance**
Control Sample	19.70±0.80^{a}	14.55±1.28^{a}	14.45±1.28^{a}	14.95±0.22^{a}	18.70±2.43^{a}	14.80±0.62^{a}	97.15±4.94^{a}
UBDFP (5%)	19.35±1.09^{ab}	14.00±0.94^{ab}	13.80±1.15^{ab}	14.60±0.60^{ab}	18.25±1.98^{a}	14.55±0.60^{a}	94.10±3.85^{b}
UBDFP (10%)	18.95±1.64^{ab}	13.95±1.03^{ab}	13.40±1.47^{b}	14.30±1.13^{bc}	17.85±2.78^{a}	14.50±0.89^{a}	92.35±5.57^{b}
UBDFP (15%)	18.80±1.74^{b}	13.60±1.70^{b}	13.25±1.74^{b}	14.15±1.18^{c}	17.20±2.02^{a}	14.65±0.67a	92.35±6.57^{b}

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

Overall, the addition of UBDFP improves both nutritional value and sensory characteristics, making the biscuits a promising functional food product. WA is a critical factor in determining the microbiological stability and shelf life of baked products. As observed in this study, WA of the biscuit samples remained relatively low across all treatments, well below threshold of 0.60, which is typically required for microbiological stability (Figure 3). WA is crucial for baked product stability, & biscuits-maintained low aw levels across all treatments, well below 0.60, ensuring microbiological safety. Low WA enhances food safety by reducing contamination risks and preserving the nutritional quality of beneficial components like fibers and antioxidants [25]. These attributes make UBDFP-enriched biscuits a convenient, safe, and long-lasting source of dietary fiber and health-promoting nutrients, especially in areas with limited access to fresh products. Sensory evaluation of biscuit samples containing various proportions of UBDFP conducted, with the findings presented in Table 7 and Figure 4. There were significant differences in appearance and surface color between control sample and 15% UBDFP substitution sample, with values of 19.70 and 18.80 for appearance, and 14.55 &13.60 for surface color, respectively. Additionally, significant differences in internal color were observed between the control and 10% and 15% substitution treatments, with values of 14.45, 13.40, and 13.25, respectively. The results also indicated a darker color with an increasing substitution percentage of UBDFP. For the texture of the biscuits, there was a significant decrease in texture values with increasing UBDFP addition.

The texture score decreased from 14.95 for the control sample to 14.30 and 14.15 for the 10% and 15% substitution treatments, respectively. No significant differences in texture were found between the control and the 5% substitution sample. The taste and aroma did not show significant differences between the control and the other treatments. Regarding overall acceptability, the control sample had the highest score (97.15), with the 5%, 10%, and 15% substitution samples recording 94.10, 92.35, and 92.35, respectively. The 5% substitution sample had the highest acceptance among the judges, consistent with findings from other studies that used date powder at similar substitution levels. Sensory analysis reveals that UBDFP substitution impacts biscuit appearance and texture. While higher substitution may decrease consumer satisfaction due to changes in texture, the significant increase in dietary fiber provides numerous health benefits, including improved gut health, cholesterol regulation, and blood sugar control. Studies confirm that dietary fibers aid in managing conditions like constipation, diabetes, and cardiovascular diseases [26]. Although sensory quality may be slightly compromised with higher UBDFP levels, the nutritional benefits of increased fiber content make these biscuits a healthier choice, particularly for individuals seeking to enhance fiber intake.

4. Conclusions

Incorporating UBDFP into biscuit production improves nutrition by increasing fiber, minerals, and fat while reducing carbohydrates, offering benefits like better digestion, glycemic control, and bone health. UBDFP-substituted biscuits are nutrient-dense and suitable for higher energy needs. However, limitations include limited substitution levels, short-term analysis, and unexamined nutrient bioavailability or long-term effects. Further research is needed on its impact on nutrient absorption, consumer preferences, and health outcomes. Despite these gaps, UBDFP shows promise as an ingredient for healthier biscuits with enhanced nutritional value.

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References

[1] K.Q. Lau, M.R. Sabran, S.R. Shafie. (2021). Utilization of vegetable and fruit by-products as functional ingredient and food. Frontiers in Nutrition. 8: 661693.

[2] A. Elfeky, J. Elfaki. (2019). A review: Date palm irrigation methods and water resources in the Kingdom of Saudi Arabia. Journal of Engineering Research and reports. 9(2): 1-11.

[3] K.L. Alharbi, J. Raman, H.-J. Shin. (2021). Date fruit and seed in nutricosmetics. Cosmetics. 8: 59.

[4] H.O. Mirghani. (2021). Dates fruits effects on blood glucose among patients with diabetes mellitus: A review and meta-analysis. Pakistan Journal of Medical Sciences. 37: 1230-1236

[5] W. Lou, H. Zhou, B. Li, G. Nataliya. (2021). Rheological, pasting and sensory properties of biscuits supplemented with grape pomace powder. Food science and technology. 42: e78421.

[6] S.M.A. Alhuzali, N.M.H. Jibrin, R.J.A. Aljaber, A.O.M. ALbisher. (2023). Dates palm (Phoenix dactylifera L.) Fruits: Nutritional Properties and Potential Applications. المجلة العربية للعلوم الزراعية. 6: 137-160.

[7] N. George, A.A. Andersson, R. Andersson, A. Kamal-Eldin. (2020). Lignin is the main determinant of total dietary fiber differences between date fruit (Phoenix dactylifera L.) varieties. NFS Journal. 21: 16-21.

[8] A.A. Ayad, L.L. Williams, D.A. Gad El-Rab, R. Ayivi, H.L. Colleran, S. Aljaloud, S.A. Ibrahim. (2020). A review of the chemical composition, nutritional and health benefits of dates for their potential use in energy nutrition bars for athletes. Cogent Food & Agriculture. 6: 1809309.

[9] M.S. El-Habbab, F. Al-Mulhim, S. Al-Eid, M. Abo El-Saad, F. Aljassas, A. Sallam, H. Ghazzawy. (2017). Assessment of post-harvest loss and waste for date palms in the Kingdom of Saudi Arabia. International Journal of Environmental and Agriculture Research. 3: 1-11.

[10] M. Ranasinghe, I. Manikas, S. Maqsood, C. Stathopoulos. (2022). Date components as promising plant-based materials to be incorporated into baked goods—A Review. Sustainability. 14: 605.

[11] H. Ibrahim, S. Alam, Y. Kurniati, S.L. Noor. (2021). The Development and Evaluation of Nutritional Content of Date Biscuits as Functional Food for Female Worker. Int. J. Pharma. Res. 13(2): 529-535.

[12] E.S. Abd El-Hady, A, H.A. Alfheeaid, M.M. Abd El-Razik, S.A. Althwab, H. Barakat. (2022). Nutritional, Physicochemical, and organoleptic properties of camel meat burger incorporating unpollinated Barhi date fruit pulp. International Journal of Food Science. 2022(1): 4581821.

[13] F. Al-Juhaimi, K. Ghafoor, M.D. Hawashin, O.N. Alsawmahi, E.E. Babiker. (2016). Effects of different levels of Moringa (Moringa oleifera) seed flour on quality attributes of beef burgers. CyTA-Journal of Food. 14: 1-9.

[14] D. Agrahar-Murugkar, P. Gulati, N. Kotwaliwale, C. Gupta. (2015). Evaluation of nutritional, textural and particle size characteristics of dough and biscuits made from composite flours containing sprouted and malted ingredients. Journal of food science and technology. 52: 5129-5137.

[15] N. Khalil, A.E. Elbeltagy, T. Aljutaily, A. Ali, M. Gadallah. (2023). Organoleptic, antioxidant activity and microbial aspects of functional biscuit formulated with date fruit fibers grown in Qassim Region. Food science and technology. 43: e95222.

[16] F. Xiao, X. Zhang, M. Niu, X. Xiang, Y. Chang, Z. Zhao, L. Xiong, S. Zhao, J. Rong, C. Tang. (2021). Gluten development and water distribution in bread dough influenced by bran components and glucose oxidase. Lwt. 137: 110427.

[17] L. Tebben, Y. Shen, Y. Li. (2018). Improvers and functional ingredients in whole wheat bread: A review of their effects on dough properties and bread quality. Trends in Food Science & Technology. 81: 10-24.

[18] K. Ghafoor, F.Y. Al-Juhaimi, E.E. Babiker, M.Z.I. Sarker, I.A.M. Ahmed. (2022). Effects of Functional Edible Coatings and Storage on Bioactive Compounds, Antioxidant Properties and Sugars in Barhi Dates. Horticulturae. 8: 1185.

[19] S. Aljaloud, H.L. Colleran, S.A. Ibrahim. (2020). Nutritional value of date fruits and potential use in nutritional bars for athletes. Food and Nutrition Sciences. 11:436.

[20] J. Dhankhar, N. Vashistha, A. Sharma. (2019). Development of biscuits by partial substitution of refined wheat flour with chickpea flour and date powder. The Journal of Microbiology, Biotechnology and Food Sciences. 8: 1093-1097.

[21] D.O. Abdelkarim, I.A. Mohamed Ahmed, K.A. Ahmed, M. Younis, H.M. Yehia, A.I. Zein El-Abedein, A. Alhamdan. (2022). Extending the Shelf Life of Fresh Khalal Barhi Dates via an Optimized Postharvest Ultrasonic Treatment. Plants. 11: 2029.

[22] L.F. Călinoiu, D.C. Vodnar. (2018). Whole grains and phenolic acids: A review on bioactivity, functionality, health benefits and bioavailability. Nutrients. 10: 1615.

[23] M.S. Blanco Canalis, M.E. Steffolani, A.E. León, P.D. Ribotta. (2017). Effect of different fibers on dough properties and biscuit quality. Journal of the Science of Food and Agriculture. 97: 1607-1615.

[24] M. Weng, Y. Li, L. Wu, H. Zheng, P. Lai, B. Tang, X. Luo. (2020). Effects of passion fruit peel flour as a dietary fibre resource on biscuit quality. Food science and technology. 41: 65-73.

[25] C. Vasile, M. Baican. (2021). Progresses in food packaging, food quality, and safety—controlled-release antioxidant and/or antimicrobial packaging. Molecules. 26: 1263.

[26] C.-B. Ioniță-Mîndrican, K. Ziani, M. Mititelu, E. Oprea, S.M. Neacşu, E. Moroșan, D.-E. Dumitrescu, A.C. Roșca, D. Drăgănescu, C. Negrei. (2022). Therapeutic benefits and dietary restrictions of fiber intake: A state of the art review. Nutrients. 14: 2641.