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Effects of dried fig flour incorporation as a natural additive on nutritional composition and sensory assessment of biscuit

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Abstract: The aim of this work is to characterize the physicochemical and techno-functional properties of dried fig flour to investigate its effect on the qualities of biscuits on the one hand and to encourage the use of this aromatic and medicinal plant in the agri-food industry. During this study, figs and wheat grains were dried and subsequently ground to obtain a flour that was used in various proportions of 0%, 50% and 100%, respectively in the manufacture of the biscuit. The flours were examined for proximate composition, polyphenol and tannin levels, along with functional properties. Flour derived from dried figs showed higher levels of crude ash, sugar, fiber, polyphenol and tannin, as well as greater water absorption capacity and density. The results indicated that incorporating dried and rehydrated fruits increased the total antioxidant activity of the biscuits compared to the control sample. The detailed organoleptic analysis, conducted through a tasting test revealed that all tasters found the dry biscuits acceptable. Biscuits formulated with 50% fig powder exhibited improved sensory attributes, including attractive colour, a crispy texture, and a more pronounced flavour. The use of this aromatic and medicinal plant in the food industry, particularly in biscuit production, holds significant potential. It enhances the nutritional value while imparting a sweet taste, distinctive flavour and natural colour. Additionally, its use contributes to improving the functional attributes of biscuit products, offering a sustainable approach to valorizing dried fig flour.

Keywords: aromatic and medicinal plant; functional properties; polyphenol; taster; valorization

In recent years, there has been an increasing demand for foods rich in dietary fiber and antioxidants. The significance of these food components has generated a substantial market for products and ingredients that are high in these nutrients. Consumption of dietary fiber and phytochemicals, such as ascorbic acid, carotenoids, polyphenols, and tocopherols has been associated with health preservation and protection against diseases such as like cancer, heart disease, and various other degenerative conditions (Shi et al. 2022). Due to their antioxidant, anti-cancer, and anti-mutagenic properties, fruits and vegetables have drawn a lot of attention recently as a source of biologically active compounds (Hijova et al. 2019).

Bakery products constitute a significant part of the human diet, primarily because they are made from cereals and possess an extended shelf life. Biscuits are among the most consumed bakery products. Nowadays, most people enjoy consuming bakery products. The increasing worldwide consumption of biscuits underscores the need for their improvement. In Algeria and other countries, biscuits are the most popular bakery item, owing to their convenience, affordability, excellent nutritional value, variety of flavours, and ex-

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tended shelf life, all of which contribute to their enormous appeal (Meilgaard et al. 2016). There are studies on the application of rice, wheat, and figs as dietary fiber sources in bread and other bakery goods (Esrafil et al. 2024).

Figs are a seasonal fruit that can be harvested twice annually, either in spring and summer or in early and late summer, depending on the variety (Veberic and Mikulic-Petkovsek 2016). They can be consumed fresh (peeled or unpeeled), dried, or made into jam and juice (Harzallah et al. 2016). Figs, whether fresh or and dried serve as important sources of trace elements such as iron, calcium, potassium), as well as vitamins like thiamine and riboflavin. Natural antioxidant compounds, including phenolics, organic acids, vitamin E and carotenoids are beneficial compounds found in a variety of fruits and vegetables and they are also present in figs (Sandhu et al. 2023). These compounds can inhibit the formation of free radicals by either reducing or donating hydrogen to other substances. Among them, phenolic compounds are particularly notable for their established antioxidant properties, and they also play a significant role in in contributing to colour, texture, and flavour (Meilgaard et al. 2016). Texture is a critical characteristic that significantly influence dough machinability and the quality of bakery products, which are widely consumed worldwide (Bourne 2002). This study aimed at evaluating the proximate chemical composition and techno functional properties of wheat and dried fig flours and to investigate the effect of substituting wheat flour with dried fig powder on the nutritional quality and the sensory attributes of the obtained biscuit.

MATERIAL AND METHODS

Dried figs

Approximately, 10 kg of non-infested, *Ficus carica* L. (*Moraceae variety*), obtained from fig trees of Panino CL L1 type, were purchased from a wholesale fruits and vegetables market situated in Mostaganem (western region of Algeria), in March 2024. The dried figs, referred to as Chriha, were mature but not fresh, characterized by caramel-coloured flesh and pastel yellow skin. They were transported to the laboratory for further analysis.

Dried figs preparation and flour processing

The whole dried figs were manually cleaned with tap water to remove any foreign matter. After draining, all samples were dried using a vacuum lyophilizer freeze dryer machine (Biobase, Gino Zhan, China) set to –80 °C for a period not exceeding 24 h. Dried figs were then milled sing a Délonghi coffee grinder and sieved through 250 µm mesh to obtain uniformly sized flour. The flours were subsequently packed into polyethylene bags and stored in a dry cabinet at 25 ± 2 °C for analysis. Dried figs were processed into flour as illustrated in Figure 1.

Physicochemical analysis

Proximate analysis. As per the guidelines provided by the Association of Official Analytical Chemists (AOAC 2010), the flours were examined for moisture, ash, crude protein, crude fat, and crude fiber levels. The method of DuBois et al. (1956) was used to determine the soluble sugars.

pH determination. The pH measurement was performed according to the instructions provided by Ngoma et al. (2019). After combining 10 g of each flour sample with 100 mL of distilled water, the mixture was allowed to stand at room temperature for half an hour. A calibrated pH meter (Adwa AD 1 200 pH/mV/ISE, Adwa Hungary kft, Romania) was used to measure the pH.

Total phenolic content measurements. The extraction of total phenols was conducted using a mod-

Figure 1. Cleaning and processing figs into flour

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ified method compared to that described by Chikpah et al. (2020). Briefly, 20 mL of acidified methanol (1% HCl) was combined with 2 g of flour. The mixture was homogenized for 2 min using an Ultraturrax homogenizer (IKA, Germany), followed by agitation with a magnetic stirrer (Zenith, China) for 20 min. It was then allowed to stand at room temperature for 24 h in the dark before centrifugation at 3 000 rpm (revolutions per minute) for 10 min. The residue was subjected to second extraction for 24 h using the same protocol, after which, the supernatant was collected and stored at 4 °C. The total phenol and tannin content was analysed in the supernatants. Total phenolic content was calculated following methodology of Singleton et al. (1 999) and reported as mg gallic acid equivalent (GAE) per 100 g flour.

Phytates. The content of phytic acid, or phytate was measured using the Reddy et al. (1982) method. A test portion of 2 g of the flour was mixed with 100 mL of HCL and allowed to stand for 5 h with periodic stirring. The extract was then filtered, and 25 mL of the filtered solution was mixed with ammonium thiocyanate. The extract is then titrated with an acidic solution of $FeCl_3$, during which the brown colour changed to a light-yellow hue as the titration approached its endpoint. Phytates can be computed using the following Equation 1:

$$\text{Phytate concentration} = \frac{\text{drawn value} \times 0.064}{100 \times \text{sample weight}} \qquad (1)$$

Functional properties

Bulk density. The Kaur and Singh (2005) technique was followed for this parameter. A graduated cylinder measuring 50 mL was filled with ten grams of flour and gently tapped ten times. The bulk density was computed by dividing the flour's weight by the flour's volume.

Water solubility. The flour's water solubility (WS) was calculated using the methodology outlined by Chikpah et al. (2020). 2 g of flour and 25 mL of distilled water were placed in a pre-weighted centrifuge tube (W1) and cooked in a water bath at 60 °C for 30 min under continuous stirring. The slurry was centrifuged (SIGMA, D-37520 Osterode am Harz, 2–16KL, (Guido Guttmann, Germany) for 30 min at 4 000 rpm. The supernatant was transferred to a pre-weighed evaporating dish (W_2) and dried at 105 °C until a constant weight (W_3) was achieved. Water solubility was computed using Equation 2.

$$\text{Water soluility} = \frac{W_3 - W_2}{\text{initial sample weight}} \times 100 \qquad (2)$$

where: W_2 – pre-weighed evaporating dish; W_3 – constant weight.

Water absorption capacity. Approach of Sosulski et al. (1976) was used to determine the flours' capacity to absorb water. One gram of the sample was mixed with 10 mL of distilled water and left to stand at room temperature (30 ± 2 °C) for 30 min. The sample was then centrifuged for 30 min at 3 000 rpm. Water absorption was analysed by calculating the percentage of water bound per gram of flour. Additionally, the method described by Sosulski et al. (1976) was also utilized to assess the oil absorption capacity. One gram of the sample was mixed with 10 mL of soybean oil (specific gravity: 0.9092) and left to stand at room temperature (30 ± 2 °C) for 30 min. The mixture was then centrifuged for 30 min at 300 rpm. The percentage of water bound per gram of flour was utilized to determine water absorption.

Oil absorption capacity. A 1 g sample of flour (W_1) was placed in a pre-weighed centrifuge tube (W_2) and mixed with 10 mL of vegetable oil. The mixture wasvortexed and left to stand at room temperature (30 ± 2 °C) for 30 min. It was then centrifuged at 300 rpm for 30 min. After centrifugation, theunabsorbed oil was thoroughly drained, and theweight of the tube containing the sample wasmeasured and recorded (W_3). According to Sosulski et al. (1976), oil absorption capacity was calculated using Equation 3.

$$\text{Oil absorption capacity} = \frac{W_3 - (W_2 + W_1)}{W_1} \times 100 \qquad (3)$$

Biscuit Preparation. Biscuits were prepared by entirely replacing wheat flour with fig flour (Table 1). The flours were manually mixed with other baking ingredients to form a uniform dough. After being divided into equal portions, the resultant dough was molded, shaped, and stamped. The stamped dough was baked for 25 min at 250 °C in a household oven. Once baked, the goods were allowed to cool before being wrapped in cellophane and kept at room temperature.

Determination of antioxidant activity. The 2,2-diphenyl-1-picrylhydrazyl (DPPH) method as outlined by Mahloko et al. (2019), was used to spectrophotometrically measure the radical scavenging activity.

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Table 1. Percentage of flour and other ingredients used for biscuit production

Flours (%)	Wheat	Fig
BWF	100	00
BFFP	50	50
BFFT	00	100
Ingredients of making biscuit (g)		
flour	400	
sugar	80	
margarine	160	
whole egg	90	
corn flour	40	
baking powder	08	

BWF – biscuit made from wheat flour; BFFP – biscuit partially made from fig flour; BFFT – biscuit entirely made from fig flour

Briefly, 0.5 g of crushed biscuit sample was put into 10 mL of 80% methanol solution at 25 °C, and left in the dark for 24 h to allow for extraction. A methanolic solution of DPPH was prepared by dissolving 2.4 mg of DPPH in 100 mL of methanol. About 0.2 mL of the obtained extract was combined with 1.5 mL of methanolic 0.1 M DPPH solution. The mixture was centrifuged for 20 min at 5 000 centrifugal force using vortex machinery. The liquid was completely combined and the supernatant was separated and used to evaluate the 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity of biscuits. After being shaken for 5 min using a mechanical shaker, the mixture was allowed to settle at room temperature (23 ± 1 °C) for one hour in the dark. The absorbance was determined using a 1 700 UV/Vis double-beam spectrophotometer Shimadzu at a wavelength of 515 nm, with methanol used as the blank. 1.5 mL of DPPH and 0.2 mL of methanol were used to create the negative control. The antioxidant activity uses Equation 4 as a measure of the percentage inhibition of DPPH free radicals.

$$\text{Antioxidant activity (\%)} = \frac{\text{Abs}_{\text{DPPH}} - \text{Abs}_{\text{sam}}}{\text{Abs}_{\text{DPPH}}} \times 100 \quad (4)$$

where: Abs_{DPPH} – absorbance of DPPH solution; Abs_{sam} – absorbance of the sample.

Instrumental measurement of colour parameters in formulated biscuits. The surface colour of three types of biscuits, each formulated with varying levels of fig flour, was evaluated using the Hunter Lab Color QUEST II Minolta CR-400 (Konica Minolta Inc., Japan). The colour measurements were recorded in the L^*, a^*, and b^* colour space system. The L^* value represents lightness, ranging from black (0) to white (100), while the a^* value indicates the transition from green to red, and the b^* value captures the shift from blue to yellow. The following equation was then used to evaluate the total colour difference (ΔE), as reported by Yang et al. (2022):

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (5)$$

where: ΔE – total colour difference; $+a^*$ – redness; $-a^*$– greenness; $+b^*$ – yellowness; $-b^*$ – blueness; L_0^* – 99.50; a_0^* ––0.06; b_0^* – –0.19, were the colour parameters of the white standard plate.

Biscuit texture. The instrumental texture measurements were carried out using a TA.XT Plus Texture Analyzer (Stable Microsystems, UK). A portable, single-column solution that can test materials properties and analyze textures up to 50 kg in force. The device's software was used to track textural properties including chewiness and hardness and construct a force-time graph (Bourne 2002).

Sensory evaluation. Twenty tasters, including male and female faculty members and students from the department of second cycle at the Higher School of Agronomy (Algeria), served as a semi-trained panel. After receiving training on the descriptive terminology of the sensory scales, the panelists were asked to rate the taste, colour, texture, and overall acceptability of the various biscuit samples using a 9–point Hedonic scale, where 1 denotes severe dislike and 9 indicates extreme liking Meilgaard et al. (2016). A white-light-

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filled laboratory with separate sensory chambers was employed (Figure 2). Randomly selected coded sample presentations were made, and between each evaluation, drinkable water was available for mouthwash.

Statistical analysis

The statistical relevance of the findings was evaluated by subjecting the study's data to one-way analysis of variance (ANOVA). The Newman-Keuls test was employed in these post hoc mean comparisons, using SPSS 20.0 statistical software. The results are presented as the mean ± standard deviation (SD), with each experiment conducted in triplicate. Prior to analysis, the normality of data distributions was assessed using the Shapiro-Wilk test. Given the symmetrical distributions, parametric statistical tests were selected for data analysis. One-way analysis of variance was conducted for between-group comparisons of biscuit samples. Principal component analysis (ACP) was also used as a descriptive and exploratory method to characterize the sensory quality structure of biscuit samples using R software (version 4.2.2). A $P < 0.05$ was established as criterion for statistical significance.

Figure 2. Tasting the biscuit samples

RESULTS AND DISCUSSION

Biochemical composition of flours. As shown in Table 2, a significant difference ($P < 0.001$) is observed between all the flours studied, with the wheat flour (WF) exhibiting the lowest moisture content. Statistical analysis of the results revealed that the pH, total lipid and crude protein content were significantly higher in WF compared to fig flour (FF). The highest mineral content ($P < 0.05$) is that of fig flour. WF contains the lowest amount of soluble sugars, while FF contains a high content of polyphenols, fiber and phytates ($P < 0.001$) (Table 2).

Statistical analysis of the results reveals that the pH of wheat flour is higher than that of FF flour (Table 2). These findings are consistent with a previous study by Wang et al. (2017) who reported a significant drop in pH values for all fig varieties after drying. A highly significant difference ($P < 0.05$) was found between all the flours studied, whose water content varied between

Table 2. Ingredient chemical composition

Parameters	Wheat	Fig	Effect ingredient type
pH	06.23 ± 0.18	04.78 ± 0.13	*
Moisture (%)	10.15 ± 1.25	25.33 ± 1.68	***
Crude ash (%)	05.01 ± 0.11	07.23 ± 0.22	**
Total fat (%)	01.45 ± 0.09	03.25 ± 0.11	***
Crude protein (%)	06.64 ± 0.23	02.87 ± 0.10	***
Soluble sugar (%)	09.17 ± 1.45	27.33 ± 1.73	***
Crude fiber (%)	0.35 ± 0.06	02.96 ± 0.09	***
Polyphenols (mg EAG·100 g DM^{-1})	44.08 ± 1.95	87.65 ± 2.33	***
Phytate (%)	0.33 ± 0.03	0.88 ± 0.07	***

*,**,***$P < 0.05$, 0.01, 0.001; values are mean ± standard deviation of triplicate determinations; $n = 2$; DM – dry matter; EAG – gallic acid equivalent

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10.15% and 25.33%. The lowest moisture content was recorded for WF flour. As specified in the DDP14 standard regarding the control of the commercial quality and marketing of dried figs (Galván et al. 2022) the moisture content must not exceed 26%. The highest mineral content ($P < 0.05$) is that of FF flour compared to wheat flour. This difference can be attributed to the types of soils in which these fig crops were grown, to agricultural practices, or even to the processing methods. Total fat, crude protein, crude fiber, polyphenols and phytate are present in considerable quantities in fig flour. According to Shi et al. (2022), dried figs are crucial for maintaining food's nutritious content and improving its sensory appeal. Additionally, fig polyphenols are linked to antioxidant activities and offer a host of other health advantages, including hepatoprotective, antihyperglycemic and antispasmodic effects.

Techno-functional characteristics of flours. As shown in Figure 3, fig flour showed high levels of water absorption capacity ($P < 0.001$), water solubility ($P < 0.001$) and density ($P < 0.05$) compared to wheat flour which showed a high level of oil absorption capacity ($P < 0.01$).

The functional properties are mainly due to their physical, chemical and structural characteristics (Sahni and Shere 2020). The highly significant difference among the flours was observed in their water absorption capacity (WAC), with FF flour exhibiting the highest value. According to Wang et al. (2017), water absorption capacity is considered a critical factor affecting a product's viscosity, swelling, and consistency, particularly during cooking. The ability of flours to hold onto water directly affects the final product's physicochemical and sensory qualities (tenderness, friability, etc). The oil absorption capacity (OAC) of food is a crucial functional characteristic. As shown in Figure 3, fig flour has a lower OAC ($P < 0.01$) compared to wheat flour (WF) probably due to its low hydrophobic protein content, which demonstrates a greater binding capacity for lipids. This result is in agreement with that reported by Es-

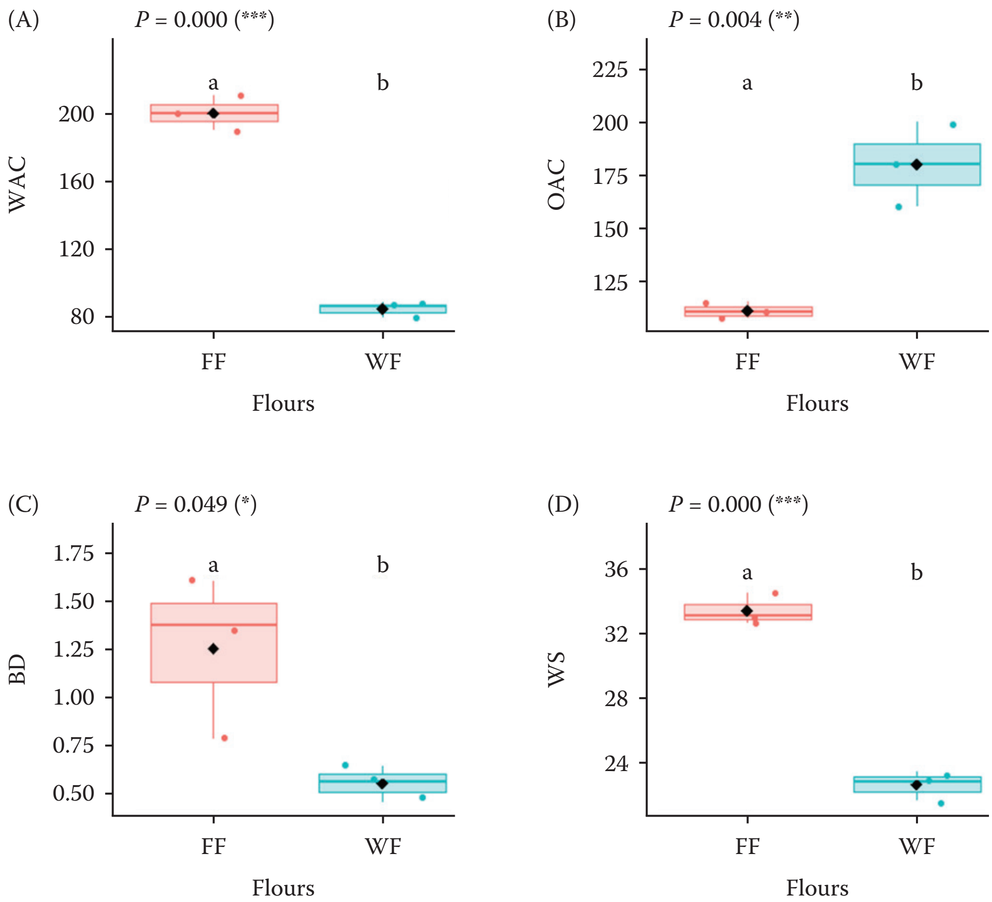

Figure 3. Functional properties of the flours

[a,b]Superscripts indicate statistically significant differences ($P < 0.05$); *,**,***$P < 0.05$, 0.01, 0.001; WF – wheat flour; FF – fig flour; WAC – water absorption capacity; OAC – oil absorption capacity; BD – bulk density; WS – water solubility

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rafil et al. (2024) who suggest that increase in the fiber content leads to a decrease in oil absorption capacity due to the aggregation of sorption sites. The bulk density of figs powder reported in this study is significantly higher than that of wheat flour, which may be attributed to its greater moisture content. The results indicated lower solubility values in the wheat flour than in the fig flour, possibly due to lower starch levels and dietary fiber content (Table 2).

Nutritional quality of biscuit. A significant difference ($P < 0.05$) is observed between all the biscuits studied (Table 3). The biscuit made with 100% fig flour (BFFT) presents the highest content in dry matter, soluble sugar and antioxidant activity ($P < 0.001$). Biscuits based on wheat flour (BWF) exhibited high levels of crude proteins and total lipids ($P < 0.05$). Significant and slightly comparable contents are noted for biscuits based on fig flour. Fig flour substitution affected significantly ($P < 0.001$) the chemical compositions of the biscuits (Table 3).

Our results are consistent with those obtained by Nakilcioğlu-Taş (2018) and show that enriching cookies with dried fig flour would improves the nutritional properties of the biscuits. As can be seen from Table 3, the lowest moisture content was recorded for BFFT biscuit. These results are similar to those obtained by Weng et al. (2021). The moisture content of the biscuit samples decreased significantly with increasing fig flour incorporation ($P < 0.05$). This could be attributed to the increase in water holding capacity due to the increase in fiber content of the biscuit samples. Hijova et al. (2019) affirmed that the reduction in water activity of biscuits containing substances, such as fiber, is caused by their ability to absorb a large amount of water, thereby reducing the amount of available water. According to Sandhu et al. (2023), low moisture content extends the shelf life of the product and prevents its deterioration during storage by inhibiting microbial growth. BFFT had the greatest ash content value, followed by BFFP. However, BWF (control) had the lowest ash content value. This difference may be attributed to the types of flours used, soils in which the studied fig variety was grown, agricultural practices, or even processing methods (Galván et al. 2022). The increase in ash content with increasing level of fig flour substitution may be associated with the presence of higher ash content in fig skin than that in wheat (Bala et al. 2015). The addition of fig seed flour to the biscuit formulation resulted in BFFT, BFFP samples with higher total fat content. This is likely due to the richness of fig seed flour in fat as shown in Table 2. According to Lillford (2011) the presence of fat in cakes gave a higher sensory perception. The high protein content in biscuits made from wheat flour (6.11%) can be attributed to the composition of wheat and its richness in essential amino acids. This value is lower than the 10.80% reported by Sahni and Shere (2020), i.e. This can be explained by the fact that the protein content negatively correlates with the diameter of the biscuits studied. According to Esrafil et al. (2024) the protein content in biscuit flour should not exceed 12%. The composition of fig flour showed a significantly higher concentration of fiber (Table 2), which allows to obtain significant amount of biscuit soluble sugar content (Table 3). Bölek (2021) reported that enriching biscuits with fruit fig seed powder would enhance the nutritional properties. The free radical DPPH is one of the most commonly used substrates for rapid and direct assessment of antioxidant activity due to the stability of its radical form and the simplicity of its analysis (Gül and Ulutürk 2019). The result revealed that the fig flour has higher total phenol and phytate contents as well as higher biscuit antioxidant activities than the

Table 3. Effect of fig rate incorporation on nutritional quality of biscuit.

Parameters	BWF	BFFP	BFFT	Fig flour impact
Dry matter (%)	35.12 ± 0.61^{c}	37.35 ± 0.77^{b}	62.02 ± 1.64^{a}	0.001**
Moisture (%)	64.88 ± 2.11^{a}	62.65 ± 1.88^{b}	37.98 ± 0.95^{c}	0.002**
Crude ash (%)	02.81 ± 0.02^{c}	03.33 ± 0.05^{ab}	03.45 ± 0.06^{a}	0.025*
Total fat (%)	02.2 ± 0.01^{c}	03.68 ± 0.05^{b}	05.80 ± 0.08^{a}	0.003**
Crude protein (%)	06.11 ± 0.09^{a}	03.6 ± 0.06^{bc}	04.00 ± 0.07^{b}	0.000***
Soluble sugars (%)	07.11 ± 0.11^{c}	15.22 ± 0.28^{b}	30.33 ± 0.45^{a}	0.000***
DPPH (%)	07.50 ± 0.17^{c}	15.33 ± 0.33^{b}	28.11 ± 0.41^{a}	0.001**

$^{a-c}$Superscripts indicate statistically significant differences ($P < 0.05$); *,**,***$P < 0.05$, 0.01, 0.001; values are mean ± standard deviation of triplicate determinations; $n = 3$; BWF – biscuit made from 100% wheat flour; BFFP – biscuit made with 50% fig flour; BFFT – biscuit made from 100% fig flour; DPPH – 2,2-diphenyl-1-picrylhydrazyl

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control biscuit. This result suggests that the fig flour and biscuit could serve as cheap functional foods.

Colour analysis. The impact of fig flour addition on colour attributes of biscuit samples is represented in Table 4.

The results agree with those of Meilgaard et al. (2016), who reported that incorporating fruit by-products alters the colour of baked biscuits. As shown in Table 4, increasing the figs flour (FF) content significantly (P < 0.01) darkened the biscuit samples. Biscuits formulated with 100% FF exhibited the most pronounced darkening with a lightness (L^*) value of 47.25 ± 1.11 whereas the control sample had a significantly (P < 0.01) higher lightness value (75.33 ± 2.86). Biscuits containing 50% FF had an intermediate lightness value of 62.48 ± 1.71. This darkening could be attributed to the presence of water-insoluble phenolic compounds and fiber in the dried figs. Bioactive compounds such as polyphenols and tannins retained in the fig flour residue can promote enzymatic browning, leading to reduced lightness and yellowness in the biscuits. Similar results were reported by Lucini Mas et al. (2022), who observed significant darkening in bakery products, such as cookies and bread, when fruit-by products were incorporated. In addition to the lightness reduction, the redness index (a^*) and ΔE values increased significantly (P < 0.001) with increasing levels of dried fig flour substitution. The highest values were observed in biscuits made with 100% (BFFT) followed by those made with 50% (BFFP) compared to the biscuit made from 100% wheat flour (BWF) (Table 4). This darker colour in the biscuits may be attributed to Maillard browning reactions, which involve both enzymatic and non-enzymatic processes. These reactions result in a darker colour compared to the control samples. The Maillard reactions are influenced by the water activity of the dried figs used in the formulation. As the water activity increases in biscuit samples supplemented with higher levels of fig flour, the degree of darkening also intensifies. This is likely due to the higher sugar and polyphenols contents in the fig flour, which provides the substrates necessary for the non-enzymatic Maillard reactions, further enhancing the creation of brown compounds and surface darkening of the biscuits (Meilgaard et al. 2016).

The texture of a biscuit is one of its key characteristics. Table 5 displays the textural profiles of the control and other formulated biscuits.

Table 5 shows a significant difference in the texture of the cookies. It was observed that the hardness seemed to influence the texture of the biscuits (P < 0.001). As reported earlier, the hardness of biscuits made with only fig flour was found to be significantly higher (P < 0.001) than that of biscuits made with wheat flour in the control group. This can be attributed to the increase in crude fiber (Hijova et al. 2019) and

Table 4. Effect of incorporation of figs flour on the colour attributes of biscuit

	BWF	BFFP	BFFT	Fig flour impact
L^*	75.33 ± 0.86^a	62.48 ± 0.71^b	47.25 ± 0.11^c	0.001**
a^*	04.22 ± 0.41^c	07.38 ± 0.13^b	11.43 ± 0.28^a	0.000***
b^*	13.26 ± 0.24^a	11.53 ± 0.33^{ab}	09.86 ± 0.45^c	0.017*
ΔE*	27.80 ± 0.41^c	39.40 ± 0.58^b	54.34 ± 0.83^a	0.000***

$^{a–c}$Superscripts indicate statistically significant differences (P < 0.05); *P < 0.05; **P < 0.01; ***P < 0.001; values are mean ± standard deviation of triplicate determinations; n = 3; BWF – biscuit made from 100% wheat flour; BFFP – biscuit made with 50% fig flour; BFFT – biscuit made from 100% fig flour; L^* – luminosity; a^* – redness indices; b^* – yellowness indices; ΔE* – total colour change

Table 5. Texture characteristics of the prepared biscuits by different formulations

Samples	BWF	BFFP	BFFT	P-value
Hardness (g) force^{-1}	2068.13 ± 1.83^c	3063.17 ± 0.77^b	4059.11 ± 0.58^a	0.000***
Chewiness (mm) distance^{-1}	03.46 ± 0.33^c	05.25 ± 0.64^b	09.75 ± 0.71^a	0.013*

$^{a–c}$Superscripts indicate statistically significant differences (P < 0.05); *,**,***P < 0.05, 0.01, 0.001; values are mean ± standard deviation of triplicate determinations; n = 3; BWF – biscuit made from 100% wheat flour; BFFP – biscuit made with 50% fig flour; BFFT – biscuit made from 100% fig flour

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fat content (Harzallah et al. 2016) in dried fig as shown in Table 1. According to Bourne (2002), the hardness of the biscuits can be influenced by the type and quantity of sucrose used in manufacturing process. The lower the amount of sucrose in the biscuit formulation, the softer the biscuits tend to be. Consumers associate the hardness of biscuits with their crispiness. The chewiness results showed significant differences between the control biscuits and those made with varying amounts of dried fig flour, which contains higher levels of insoluble dietary fiber. The BFFT biscuit exhibits greater chewiness compared to the other formulated biscuit (Table 5). These differences might be attributed to the structure of the cookies, as well as to the ingredient composition, which reduces gluten formation and can lead to large force fluctuations (Shi et al. 2022). According to Lillford (2011), the moisture content is the contributing factor to the reduction in chewiness in biscuits.

Sensory properties. The multivariate analysis investigates the sensory characteristics of three types of biscuits. Six parameters such as: colour, appearance, odour, texture, sweetness, acceptability are used as explanatory quantitative variables, while the biscuit type, determined by the dried fig incorporation rate, is treated as a qualitative variable. The application of principal component (ACP) treatment revealed that the first two principal components explain 99.84% of the total variability (inertia) in the matrix (Figure 4A). The first ACP axis alone accounts for 56.79% of the total variability. This axis is positively correlated with colour (r = +0.70; $\cos^2$ = +0.49), odour (r = +0.71; $\cos^2$ = +0.50), and sweetness (r = +0.56; $\cos^2$ = +0.31). Conversely, it is negatively correlated with appearance (r = -0.99; $\cos^2$ = –0.99) and acceptability (r = –0.98; $\cos^2$ = –0.99) (Figure 4A). The 2nd ACP axis explains 41.36% of the total variance, and is characterized by a strong positive correlation with texture (r = +0.91; $\cos^2$ = +0.83) and sweetness (r = +0.83; $\cos^2$ = +0.69), while exhibiting strong negative correlation with colour (r = –0.70; $\cos^2$ = –0.48) and odour (r = -0.68; $\cos^2$ = –0.47) (Figure 4A). The in-depth ACP analysis of the 'Biscuit samples' revealed three groups (Figure 4B). The in-depth ACP of the 'Biscuit samples' reveals that BFFT shows higher texture score compared to BWF and exhibits higher sweetness, odour and colour scores compared to both BWF and BFFP. On the other hand, the BFFP shows higher texture score compared to BWF and demonstrates higher appearance and acceptability scores compared to BFFT. Meanwhile, BWF exhibits higher appearance and acceptability scores in comparison to BFFT.

The colour appreciation scores of wheat flour shortbread are higher than 6 with a preference for wheat flour biscuits (9.16 ± 0.92) but lower in texture (3.97 ± 1.11) (Figure 4). For all the samples studied, BWF and BFFP biscuits recorded the highest appearance appreciation scores, moreover, the lowest score was that of BFFT (4.33 ± 1.12). The results illustrated in figure 4 show that the odour of the biscuit made with 40% fig flour (BFFP) is the least appreciated by the panelists, receiving a lower score of 8.22 ± 0.88. In contrast, the biscuit made exclusively with wheat flour (BWF) recorded a significantly higher score (8.01 ± 0.66).

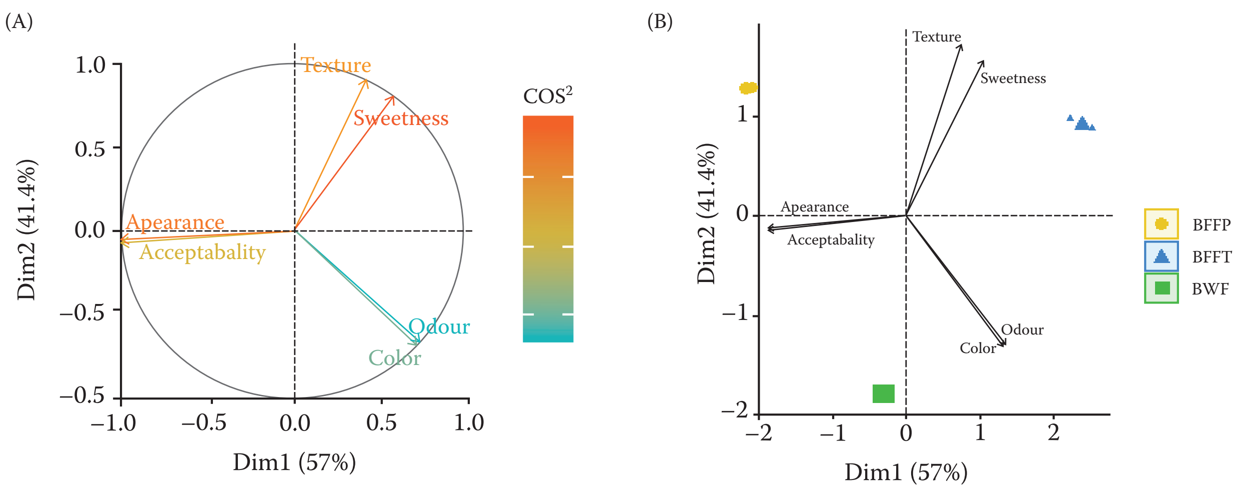

Figure 4. Principal component analysis (ACP) on the standardized matrix of sensory parameters of three types of dried fig flour enriched biscuit: (A) correlation circle, (B) factorial plan (Dim1 vs Dim2)
BWF – biscuit made from 100% wheat flour; BFFP – biscuit made with 50% fig flour; BFFT – biscuit made from 100% fig flour

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The sweetness appreciation scores were higher especially for the biscuit made with 100% fig flour (BFFT) 7.97 ± 1.84. According to Figure 4B, the BFFP and BWF shortbreads obtained higher scores (7.75 ± 2.80), (6.68 ± 1.33), respectively for acceptability compared to the BFFT prepared only with fig flour (3.45 ± 0.86). Fig flour replacement increased ($P < 0.05$) the sensory scores of biscuits in terms of odour, taste, texture and acceptability, except for colour (Figure 4).

Compared to the BWF, those made from fig flour received significantly lower sensory score for colour. This difference may be attributed to a greater presence of reducing sugar (provided by inulin), which enhances the interaction between the reducing sugar and amino acid, promoting the Maillard-type reaction (Chevallier et al. 2000). This forms brown polymers or melanoidins, leading to colour development throughout the biscuit manufacturing process (Bala et al. 2015). For all the samples studied, BWF and BFFP biscuits received the highest appearance appreciation scores while BFFT biscuits recorded the lowest score (Figure 4). Biscuit appearance is influenced factors such as colour, texture and the flour's oil absorption capacity, which contributes to the biscuits' fat content. Wheat flour biscuit showed significantly higher score for odour and taste. According to Topkaya and Isik (2019), the use of fiber sources results in a decrease in odour, flavour, and overall impression values of the biscuit samples compared to the control samples. Taste scores are influenced by the tannin content present in the flour. Tannins have an astringent taste, which can be perceived as a dry sensation or bitterness. However, biscuits made with fig flour show better scores for texture and sweetness. This may be due to the richness of figs in fat and its low protein content, making the biscuit tender and more appreciated by tasters. As shown from Figure 4, biscuits containing 50% fig flour, as well as and those from the control batch, received higher scores for acceptability compared to BFFT biscuits made entirely with fig flour only. The overall impression directly influences consumer preference and is the most important factor affecting consumers' final judgment. A significant difference in appreciation among the biscuits studied was observed. It appears that substituting 50% fig flour enhanced taster preference.

CONCLUSION

The valorization of aromatic and medicinal plants such as dried figs for the formulation of new food products based on fig flour presents a promising avenue for enhancing the nutritional and sensory profile of consumer goods. This study demonstrates that fig flour can be effectively utilized to produce biscuits with improved nutritional quality, notably rich in fiber content and bioactive compounds. These enhancements result in increased antioxidant activity and total phenolic content in the final product. The prepared biscuits have sparked consumer curiosity and received positive feedback. Sensory analysis revealed that some tasters preferred the colour and the smell of the BWF biscuits while others favoured the sweetness, the texture and the intense flavour of the BFFP Biscuit made with 50% fig flour. In future studies, the focus will be on determining the vitamins and the glycemic index of biscuits. Additionally, establishing industrial partnership for the production of gluten-free fig flour-based products will be explored, with the aim of improving and diversifying the diet of celiac patients.

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