

Nutritional, antioxidant, and sensory properties of innovative onion pie produced from whole wheat flour, carob beans flour, onion, scallions, and roasted Seaweeds

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Abstract

Snack foods have experienced substantial growth in consumption globally, appealing to various age groups and becoming a significant segment of the food industry. The current investigation aimed to assess the nutritional, antioxidant, and sensory characteristics of an unconventional pie prepared from brown wheat flour (BWF), carob bean flour (CBF), onion, scallions, and roasted seaweeds. Chemical composition, minerals content, functional properties, total phenolics, total flavonoids, and antioxidants activity (DPPH), and phenolic profile of CBF, BWF, and binary combinations were evaluated. Five pies using different formulas (CGR0, CGR1, CGR2, CGR3, CGR4, and CGR5) were developed, where CGR0 serving as the control sample with 100% BWF. The other formulations (CGR1–CGR5) are binary combinations of BWF and CBF at various ratios (90:10, 80:20, 70:30, 60:40, and 50:50%). The onion pie samples were assayed for proximate composition, minerals, and sensory properties. CBF is rich in dietary fibers, with a content of 12.73%, substantial ash (4.79%), and carbohydrates (74.36%). Blending BWF with CBF significantly enhances the functional properties of the mixture, as indicated by improved WAC, AOC, EA, and FC compared to BWF. The addition of CBF into BWF in produced pie recipes led to significant increases in Fat, fiber, and ash. Additionally, substituting BWF with CBF in pie samples led to substantial decreases in carbohydrate content. The highest content of micro- and macro-elements was found in CGR5 samples, whereas the lowest was found in control samples CGR0. The results found that incorporating CBF into onion pie samples at levels between 10% to 40% can positively impact the sensory acceptability of the produced pie samples.

Keywords: antioxidants; carob, diet; food intake; functional properties; onion; phenolic; pie

Introduction

A high-quality diet is crucial in sustaining human health and well-being, meeting basic nutritional needs, and supporting bodily functions (Burchi *et al.*, 2011). The evolution of food production and the food industry has led to an increased focus on the quality and innovation of food products to meet nutritional requirements (Alamir

& Preedy, 2013). Today's food culture is moving away from pharmaceuticals and towards functional foods and natural nutraceuticals (Al Ali *et al.*, 2021). Functional nourishment not only supplies essential nutrients but also gives strength and assists with reducing the risk of community disease, promoting gastrointestinal cleaning (Cencic & Chingwaru, 2010). Snack foods are one of the most rapidly expanding food industry categories, with

consumption increasing significantly in recent years across all age groups globally (Mireault *et al.*, 2023). On the contrary, consumption of unhealthy- high in energy snacks is a significant risk factor for developing obesity and cardiovascular disease (Aljefree *et al.*, 2022). Snacking is crucial in helping adolescents meet their daily dietary requirements for proper growth and development. Research indicates that nutritious snacks can effectively increase adolescents' body mass index, weight, protein intake, vitamin C, and zinc levels, contributing to improved nutritional status (Larson *et al.*, 2016). However, disparities exist in snacking behaviors based on socioeconomic status, with adolescents from low-income households having lower odds of consuming milk, dairy, and fruits as snacks while consuming more beverages, added sugar, and less fiber than their high-income counterparts (Vidal *et al.*, 2024). Factors influencing adolescents' eating behaviors include individual (such as taste and time constraints), social (like parental influence), community (including school food environment), and macrosystem factors (such as digital tools) (Gangrade *et al.*, 2021). In this regard, consumption of processed snacks is increasing in poor and middle-income Asian, Latin American, and African countries (Sharma *et al.*, 2019). Pie is a type of bakery food composed of pie shells and garnishes. Pies are typically consumed as snacks by kids, adolescents, and adults (Hartati & Royanda, 2021).

Carob (*Ceratonia siliqua*) flour is made from carob beans and has various applications in food products. It has been used as a partial replacement for wheat flour in gluten-free cakes and cookies, resulting in changes in the texture and acceptability of the final products (Benković *et al.*, 2019; García-Díez *et al.*, 2022). Carob flour has been successfully combined with cocoa to create a blend that is less bitter and rich in dietary fiber (~55%) and polyphenols, making it more appealing to consumers. This blend offers a high content of dietary fiber, methylxanthines, and polyphenols, with a significant portion as non-extractable proanthocyanidins, contributing to its potential health benefits. Furthermore, carob flour has been found to have a high antioxidant capacity, making it a valuable ingredient in functional foods like chocolate, where it can enhance the antioxidant function when incorporated into the recipe. The combination of carob and cocoa improves the product's nutritional profile and enhances its sensory attributes, potentially increasing consumer acceptance and providing a palatable alternative to traditional cocoa products. (Berk *et al.*, 2017). Additionally, carob flour has been used in developing a new cocoa and carob-based pastry filling, which influenced the rheological and textural properties of the filling (Roman *et al.*, 2017). Carob flour is rich in dietary fiber (56%), minerals, and amino acids. Its low

fat content makes it a valuable ingredient in gluten-free and functional foods (Issaoui *et al.*, 2019). Carob flour, derived from the roasted fruits of *Ceratonia siliqua* L., has acquired popularity for its unique composition and potential health benefits. This food item has a high sugar content (>50%), dietary fibers (~11%), minerals (Mg, Fe, P, Zn, Ca, K, Na), low protein (3-4%) and fatty substances (0.2-0.8%) levels, and significant amounts of phenolic components (e.g., gallic acid, hydrolyzable and condensed tannins) as well as vitamins (e.g., E, D, C, B6, folic acid) (Papageorgiou *et al.*, 2020). Carob pods are commonly employed in food manufacturing due to their high nutritional value, functional characteristics, and sensory performance (Tounsi *et al.*, 2017).

The onion (*Allium cepa* L.) is the most commonly grown species in the *Allium* genus. Its bulb is widely used in culinary techniques to enhance the flavor of many dishes (Liguori *et al.*, 2017). Onion is a traditional nutraceutical plant with antiviral, antidiabetic, antioxidant, anti-inflammatory properties and culinary value (Sagar *et al.*, 2022). This multipurpose crop includes bioactive substances such as organosulfur compounds, flavonoids, ascorbic acid, and prebiotics, which contribute to its health advantages, including anticarcinogenic, anti-inflammatory, and cardioprotective properties (Singh & Khar, 2022). Furthermore, onion's bioactive components have powerful antioxidant properties, making it an essential dietary supplement for countering cell oxidative stress. The widespread usage of onion in culinary and medical areas emphasizes its relevance as a multifaceted plant with significant health-promoting properties (Gnanasundari *et al.*, 2022). Green onions, commonly known as scallions, possess multiple health advantages. These substances include anti-cancer sulfur compounds that may contribute to inhibiting liver, colon, prostate, and lung cancer (Upadhyay, 2017), as well as antibacterial, antithrombotic, and anti-hyperlipidemic effects (Saha, 2013). Green onion root extract has been found to have anti-oxidation properties, inhibiting melanin synthesis and improving moisture retention and whitening effects on the skin (Chen *et al.*, 2019). Green onions also provide health benefits for the human body, nourishing the heart and kidneys, helping the spleen and digestive system, and improving blood circulation (Kim *et al.*, 2023). In this regard, Green onions are high in total nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and micronutrients, including manganese, iron, copper, and zinc (Upadhyay, 2017). Green onions are also high in organic matter, minerals, and microelements, which makes them a healthy supplement to any diet (Kim *et al.*, 2023). Additionally, green onions contain allylsulfides and flavonoids, including quercetin, which have antioxidant properties and can help reduce cholesterol levels (Rekowska *et al.*, 2018). Using green onions in cooking

can enhance food flavor and provide health benefits (Kim *et al.*, 2023). Green onions are a valuable dietary ingredient that can contribute to a healthy and nutritious diet (Kumar *et al.*, 2020).

Seaweed is marine algae that grow through natural shock or pond culture. Seaweeds do not have true roots or leaves. They are attached to base materials such as sand, mud, pebbles, and shells or range from tide level to great depths in the oceans and seas. Seaweeds are currently employed in the food, chemical, textile, and agriculture industries, as well as pharmaceuticals and medical (Dhargalkar & Kavlekar, 2004). Some European countries, such as France, have established specific regulations concerning the application of seaweeds for human consumption as a nontraditional source of mineral nutrients, macro elements, and trace elements due to their high dietary fiber content, carbohydrate content, low-calorie content, and good source of vitamins A, B1, B12, C, D, E, riboflavin, niacin, pantothenic acid, and folic acid, in addition to minerals Ca, P, Na, and K, and vitamins A and C, as well as bio-protective characteristics such as antioxidants and antimicrobials (Circuncisão *et al.*, 2018; Peñalver *et al.*, 2020). Proteins with adequate levels of essential amino acids (EAA) are vital components of nutritional value. From this aspect, red and green seaweeds have a greater protein content than brown seaweeds, with an average dry matter of 10-30%. (Machado *et al.*, 2020). Seaweed contains extremely few lipids, ranging from 1 to 5% of dry seaweed content. While polyunsaturated ω -3 and ω -6 fatty acids are the main components of these lipids, and they effectively minimize the risk of diabetes, osteoporosis, and cardiovascular disease (Mišurcová *et al.*, 2011).

While studies have explored the development of various functional food products like pizza bases (Difonzo *et al.*, 2023), protein bars, date candy, sweet potato pie, and Caprese pate (Ali, 2024), there is a gap in research specifically focusing on the nutritional and sensorial properties of onion pie as a functional food. Functional foods, enriched with bioactive compounds, have gained popularity due to their potential health benefits in preventing chronic diseases like cardiovascular diseases and obesity (Sagar *et al.*, 2022). Given the increasing consumer demand for added-value foods, investigating incorporating ingredients like onions into pies could provide valuable insights into creating nutritious, sensory-appealing, functional food options that cater to individuals seeking both health benefits and enjoyable eating experiences. Therefore, the current study's main objective is to evaluate the nutritional, antioxidant, and sensory characteristics of an innovative pie made from whole wheat flour, carob bean flour, onion scallions, and roasted Seaweeds.

Materials

Carob bean flour (CBF) and Roasted seaweed (RSW) were ordered online from Amazon.sa (<https://www.amazon.sa/-/en/>).

Brown flour (BF) (Whole wheat flour, Aloula Flour company, Jeddah, 22312, Saudi Arabia), yeast (Lesaffre, Marcq, France), salt, sugar, dried mint, dried thyme, fresh hot green pepper, onions and green onions were obtained from Danube Hypermarket, Al Safra, Buraydah 52383, Saudi Arabia.

Chemicals were purchased from Sigma Chemical Co. (St. Louis, MO, USA). All chemicals used will be of analytical reagent grade.

Methods

Preparation of pie formulae

Five pies with different formulations (CGR0, CGR1, CGR2, CGR3, CGR4, and CGR5) were produced using recipes in Table 1, where CGR0 is the control sample with 100% BF. The other formulations (CGR1-CGR5) consist of binary mixtures of BF and CBF at different ratios (90:10, 80:20, 70:30, 60:40, and 50:50%). The study aimed to explore the impact of these different compositions on the properties of the pies. Concerning the other additional ingredients were added at the same concentrations for all formulas. Pie products were manufactured according to the procedure stated in AACC (2002). First, dry ingredients (BF, binary mixture flour, RSW, yeast, salt, sugar, dried mint, dried thyme, fresh hot green pepper, chopped onions, and green onions) were mixed in a mixing bowl for 1 min. Then, water was added and blended slowly for 5 minutes. Dough samples were proofed in a cabinet at 38 °C and 80% RH for one hour. The fermented dough was divided into 150 g pieces. The pieces were then inserted into a stainless steel pan greased with olive oil for a proofing process at 38 °C, 85% RH for 10 min. The baking process was done in an electric oven for 15 min at 200 °C. The baked samples were allowed to cool at room temperature ~25°C. The finished samples were packed in low-density polyethylene bags and kept at -25°C for further analysis.

Analytical methods

Chemical composition analysis

The chemical composition was analyzed using the AOAC's Official Methods of Analysis (1995), which include moisture (air draft oven method, AOAC

Table 1. Recipes of different pie products formulated with different levels of BWF and CBF.

Ingredients	Formulas g/100g					
	CGR0	CGR1	CGR2	CGR3	CGR4	CGR5
BWF	100	90	80	70	60	50
CBF	0	10	20	30	40	50
RSW	2	2	2	2	2	2
Yeast	2	2	2	2	2	2
Salt	2.7	2.7	2.7	2.7	2.7	2.7
Sugar	2	2	2	2	2	2
Dried mint	2	2	2	2	2	2
Dried thyme	3	3	3	3	3	3
Hot green pepper	3	3	3	3	3	3
Chopped onions	42	42	42	42	42	42
Green onions	42	42	42	42	42	42
Cold water	132	137	146	153	157	161
Olive oil	10	10	10	10	10	10

Control (CGR0) pies were produced from 100 % BWF, CGR1, CGR2, CGR3, CGR4, and CGR5 formulations contain binary combinations of BWF and CBF at levels of (90:10, 80:20, 70:30, 60:40, and 50:50%), respectively.

method no. 925.09B), crude ether extract (soxhlet extraction method, method no. 950.36), total protein content (Micro-Kjeldahl method, AOAC method no. 950.36).

The total carbohydrate will be computed as the difference. The energy value (kcal/100 g) was calculated using the below equation (Montowska *et al.*, 2019).

$$\text{Energy (kcal/100 g)} = [(9 \times \text{lipids}\%) + (4 \times \text{proteins}\%) + (2 \times \text{fiber}\%) + (4 \times \text{carbohydrates}\%)]$$

Minerals content

Mineral contents in a diluted solution of ashed samples were measured using flame atomic absorption spectroscopy (3300 Perkin-Elmer), as described by Althwab *et al.* in 2021.

Functional properties of BF and CBF

The functional characteristics of native and composite flours, including water absorption capacity (WAC, %), oil absorption capacity (AOC, %), foam capacity (FC, %), and emulsion activity (EA, %), were evaluated based on the method described by Zielińska *et al.* (2018).

Bioactive compounds

Total phenolic content determination

The phenolics of samples were determined using the previous methodologies described by (Li *et al.*, 2007). Total phenolic amounts were calculated using a gallic acid

calibration curve. The results were expressed as mg of gallic acid equivalent per g dry weight.

Determination of total flavonoid content

The total flavonoid content was determined using the method described by (Ali *et al.*, 2020). The total flavonoid concentration is expressed as mg quercetin equivalents per g dry weight.

Antioxidant assessment

Scavenging DPPH radicals

The DPPH (2,2-diphenyl-1-picrylhydrazyl) technique was used to assess extracts' radical scavenging activity, as Ali *et al.* (2020) reported. The radical-scavenging activity was expressed as a percentage of inhibition and is calculated using the equation:

$$\% \text{ Radical scavenging activity} = \frac{(\text{Abs control} - \text{Abs sample})}{\text{Abs control}} \times 100$$

where Abs control means the absorbance of the DPPH solution without the tested sample, and Abs sample means the absorbance of the DPPH solution with the tested sample.

Sensory evaluation

The sensory evaluation procedures were authorized by the Auckland University of Technology Study's Ethics Committee (AUTEK ethic application 16/340). To achieve accurate results, panelists were provided

instructions before the sensory evaluation. Fifty panelists examined the pie samples. The panelists were randomly picked from Qassim University's College of Agriculture and Food, Buraydah, Qassim, Saudi Arabia students and staff. The panelists' ages ranged from 20 to 45. The sensory evaluation was conducted in a temperature-controlled environment at 25 °C, lighted by daylight fluorescent lights. The sensory assessment was conducted in separate booths adhering to ISO-DP6658 (2005) guidelines. The pie samples were cut into equal slices and placed on white-coded plates. The pie samples were rated on a 9-point hedonic scale, including appearance, taste, texture, odor, color, and overall acceptance (Ali *et al.*, 2022). Water bottles were offered to panelists to rinse their mouths in between sampling.

Statistical analysis

Except for the sensory evaluation findings ($n = 50$), all results were statistically examined in triplicate. Data were analyzed using one-way analysis of variance (ANOVA) at $p = 0.05$ (a p -value of less than 0.05 was used to designate statistical significance), followed by Duncan's new multiple-range tests to evaluate significant differences between means, as reported by Gomez and Gomez (1984).

Results and Discussions

Proximate composition (g/100 g dry weight basis), minerals content (mg/100g), functional properties, total phenolic, total flavonoids and antioxidants activity (DPPH) of carob beans flour (CBF), Brown-wheat flour and binary combinations of them

Table 2 illustrates the chemical composition, mineral content, functional characteristics, total phenolics, total flavonoids, and antioxidant activity (DPPH) of carob bean flour (CBF), brown wheat flour and their binary combinations. Based on the obtained results, the moisture content of whole wheat flour (brown flour) was 9.91%, falling within the recommended range to prevent microbial development. In comparison, carob flour had a lower moisture content of 7.22%. Additionally, it is advised to maintain water activity between 0.60–0.65 to inhibit microbial growth (Mercer, 2008). Carob bean flour possesses considerable amounts of crude fiber, ash, and carbohydrates (12.73, 4.79, and 74.36%, respectively). These findings agree with Avallone *et al.*, 1997 who stated that Carob bean flour contains around 45 % carbohydrates and 3–6 % ash. In this regard, Higazy *et al.* (2018) found that CBF had a high crude fiber content ($11.52 \pm 1.51\%$), while the carbohydrate amount ($68.54 \pm 0.31\%$) was significantly higher. The results also revealed that CBF possesses moderate quantities of protein (6.43%) alongside

small fat concentrations (1.69%). The roasted carob powder (RCP) possesses 9.00, 5.82, 2.84, and 0.74% moisture, protein, ash, and fat, respectively (Yousif & Alghzawi, 2000). Brown wheat flour (BWF) is primarily comprised of carbohydrates (83.53%), with 9.87% crude protein and minor levels of fiber (4.00%). Wheat flour (WF) quality depends on its chemical composition. Wheat flour is mainly composed of protein (10–12%) and starch (70–75%), with a small percentage of polysaccharides (2–3%), along with lipids (2%) (Goesaert *et al.*, 2005). Mixing wheat flour with various quantities of CBF significantly reduced the moisture content of composite flours. The moisture quantity of the composite flour samples varied from 8.50% to 9.40%, which indicates a significant difference ($P < 0.05$) from the control sample (100% BWF). The moisture content reduction for the composite flour suggests that it may be kept for a long time without spoilage. This shows the flour's shelf-life stability. Mixing BWF with different proportions (10–50%) of CBF resulted in significant improvements in the resulting composite flours' fat, ash, and dietary fiber content. The fat content of CBF was significantly greater than BWF. The fat percentages of the composite flour ranged from 0.97% to 1.29%. These values were significantly higher ($P < 0.05$) than the BWF, which had a fat level of 0.87%. These increments in the fat content of composite flours were attributed to the blending effect of CBF with BWF. CBF possessed significantly greater crude fiber than BWF. The crude fiber content of the composite flours ranged from 4.91% to 8.43%, which exceeded that of the BWF (4.00%). The fiber content of composite flours differed significantly from the control flour (BWF) ($P < 0.05$). The addition of CBF into composite flour caused significant increases in crude fiber content, which may be attributed to CBF's higher crude fiber content than BWF. Flour with a high crude fiber content is advantageous for bakery products because it improves digestion and lowers the risk of chronic diseases, including coronary artery disease, cerebrovascular accident, and diabetic complications (Ali *et al.*, 2022). The ash content of food items estimates the total quantity of elements present in the food products (Althwab *et al.*, 2021). The composite flours contained significantly more total ash (2.09%–3.26%) than the control flour, BWF (1.73%). The ash content of composite flours increased significantly ($p < 0.05$) as CBF replacement increased from 10% to 50%. Lower protein and carbohydrate content in CBF than in BWF contributed significantly to reducing the quantities of protein and carbohydrates in the produced composite flours (Table 2). The energy values of flour samples varied between 363.83 and 389.43 kCal/100 g. Whole wheat flour exhibited the highest energy value at 389.43 kCal/100 g, while carob flour had the lowest at 363.83 kCal/100 g. Blending wheat flour with different proportions of carob flour led to notable reductions in energy values due to the high fiber content of carob flour, as indicated in Table 2. Carob flour's rich fiber composition

Table 2. Proximate composition (g/100 g dry weight basis), minerals content (mg/100g), functional properties, total phenolics, total flavonoids and antioxidants activity (DPPH) of carob beans flour (CBF), Brown wheat flour and binary combinations of them.

Components (g/100 g dry weight basis)	BWF	CBF	BWF %+ CBF %				
			90: 10	80: 20	70: 30	60: 40	50: 50
Moisture	9.91 ^a ±0.98	7.22 ^{de} ±0.87	9.54 ^{ab} ±0.45	9.40 ^b ±0.98	9.14 ^c ±0.64	8.85 ^{cd} ±1.68	8.50 ^d ±0.74
Crude protein	9.87 ^a ±0.75	6.43 ^e ±0.54	9.50 ^{ab} ±0.67	9.20 ^b ±0.87	8.86 ^c ±0.52	8.45 ^d ±1.05	8.15 ^d ±0.69
Fat content	0.87 ^e ±0.29	1.69 ^a ±0.04	0.97 ^e ±0.01	1.05 ^d ±0.02	1.16 ^c ±0.01	1.22 ^{bc} ±0.03	1.29 ^b ±0.03
Dietary fibers	4.00 ^a ±0.15	12.73 ^a ±0.87	4.91 ^l ±0.25	5.77 ^e ±0.65	6.65 ^d ±0.68	7.52 ^c ±0.87	8.43 ^b ±0.87
Ash	1.73 ^a ±0.02	4.79 ^a ±0.15	2.09 ^g ±0.07	2.37 ^e ±0.05	2.65 ^d ±0.06	3.00 ^c ±0.08	3.26 ^b ±0.24
Total carbohydrates*	83.53 ^a ±2.58	74.36 ^e ±2.45	82.53 ^a ±2.69	81.61 ^{ab} ±3.51	80.68 ^{ab} ±1.98	79.81 ^b ±2.69	78.87 ^b ±3.24
Energy value (kCal/100 g)	389.43 ^a ±0.79	363.83 ^a ±0.82	386.67 ^{ab} ±0.76	384.23 ^b ±1.04	381.90 ^c ±0.66	379.06 ^c ±0.95	376.55 ^d ±1.03
Mineral analysis (mg/100g)							
Na	7.73 ^a ±0.27	206.64 ^a ±8.12	28.12 ^f ±3.06	47.81 ^e ±4.88	68.10 ^d ±2.13	87.32 ^c ±11.08	108.09 ^b ±7.65
K	419.14 ^a ±5.23	2621.09 ^a ±633	640.34 ^f ±4.23	861.53 ^e ±9.16	1080.73 ^d ±2.44	1299.92 ^c ±13.12	1520.12 ^b ±11.09
Ca	45.62 ^a ±1.58	630.19 ^a ±5.10	105.08 ^f ±3.55	163.53 ^e ±2.76	221.99 ^d ±4.75	278.45 ^c ±3.98	338.91 ^b ±5.73
Mg	366.06 ^a ±3.69	131.80 ^a ±4.30	343.63 ^b ±7.18	320.21 ^c ±2.19	296.78 ^d ±12.01	273.36 ^e ±7.02	249.93 ^f ±2.08
P	385.74 ^f ±4.25	953.17 ^a ±6.13	442.38 ^e ±8.14	499.03 ^d ±4.81	554.67 ^c ±8.32	613.31 ^b ±6.16	668.96 ^b ±7.14
Fe	4.56 ^f ±0.28	6.13 ^a ±0.25	4.74 ^e ±0.22	4.89 ^{cd} ±0.31	5.06 ^c ±0.23	5.19 ^b ±0.12	5.38 ^b ±0.16
Zn	7.42 ^a ±0.87	0.46 ^a ±0.02	6.72 ^b ±0.04	6.03 ^c ±0.08	5.33 ^d ±0.05	4.64 ^e ±0.09	3.94 ^f ±0.03
Cu	1.27 ^a ±0.06	0.37 ^f ±0.03	1.18 ^b ±0.02	1.09 ^c ±0.03	1.00 ^{cd} ±0.02	0.91 ^d ±0.04	0.82 ^e ±0.04
Mn	2.78 ^a ±0.07	ND	2.50 ^b ±0.09	2.22 ^c ±0.08	1.95 ^d ±0.05	1.67 ^e ±0.09	1.39 ^f ±0.00
Functional properties							
WAC %	143.67 ^a ±4.09	274.14 ^a ±3.12	156.72 ^f ±2.17	169.76 ^e ±3.16	182.81 ^d ±2.01	195.86 ^c ±3.43	208.91 ^b ±4.11
OAC %	135.45 ^a ±3.13	267.50 ^a ±2.25	149.66 ^f ±3.27	161.86 ^e ±5.14	177.07 ^d ±4.16	183.27 ^c ±2.26	202.48 ^b ±4.86
FC %	17.88 ^{de} ±1.19	22.12 ^a ±1.07	18.30 ^d ±0.77	18.73 ^{cd} ±0.98	19.15 ^c ±2.08	19.58 ^{bc} ±1.78	20.00 ^b ±2.12
EA %	15.24 ^f ±2.07	45.56 ^a ±3.13	18.27 ^e ±1.94	21.30 ^{de} ±1.83	24.34 ^d ±2.14	27.37 ^{cd} ±1.17	30.70 ^b ±2.21
Parameter							
Total Phenolics (mg gallic acid / g DW)	1.26 ^f ±0.08	16.33 ^a ±0.74	2.77 ^e ±0.12	4.30 ^d ±0.74	5.88 ^c ±0.97	7.19 ^{bc} ±1.08	8.90 ^b ±.66
Total flavonoids (mg quercetin acid / g DW)	0.26 ^a ±0.03	3.16 ^a ±0.24	0.55 ^f ±0.15	0.84 ^e ±0.08	1.13 ^d ±0.16	1.42 ^c ±0.19	1.71 ^b ±0.20
Free radical scavenging (%)	16.44 ^f ±0.75	76.23 ^a ±0.88	22.52 ^e ±1.13	28.37 ^d ±2.03	35.16 ^{cd} ±1.19	40.61 ^c ±2.17	47.10 ^b ±1.78

Values are means ± SD of five determinations. Values are Mean ± standard deviation of five replicates. Values with different superscript letters in the same row differ significantly ($p \leq 0.05$).

*By difference. ND means not detected.

likely contributed to the decreased energy values observed in the blended flours. This suggests that incorporating carob flour into wheat flour formulations can be a strategic approach to reduce the energy content of the final product, which aligns with the broader nutritional goals of enhancing the health profile of food products.

The mineral content of carob bean flour (CBF), brown wheat flour, and their binary combinations is shown

in Table 2. Generally, BWF contains less mineral content than CBF. The predominate minerals in CBF were potassium, phosphorus, calcium, sodium, and magnesium, with concentrations of 2621.09 mg/100 g, 953.17 mg/100 g, 630.19 mg/100 g, 206.64 mg/100 g, and 131.80 mg/100 g dry weight basis, respectively. These findings align with those of Özcan *et al.*, 2007, who declared that CBF can serve as a good source of macro- and microelements. Iron content in CBF was around

1.34 times as high as in the BWF. The amount of ash in composites incorporated with CBF ranged from 2.09 to 3.26 %, corresponding to the amount of minerals present in the sample. Generally, incorporating CBF into whole wheat flour results in significant ($P \leq 0.05$) increases in composite flour's macro and microelements, except zinc, iron, and copper. The concentrations of these elements in the composite flours increased significantly ($P < 0.05$) with increasing CBF addition in the produced blends.

Table 2 illustrates the functional qualities of carob bean flour (CBF), brown wheat flour and their binary combinations. Flour samples' water absorption capacity (WAC) ranged from 143.67 to 274.14% (Table 2). CBF exhibited the greatest WAC (274.14%, $p < 0.05$), whereas whole wheat flour had the lowest (143.67%). The high WAC of CBF might be attributed to the high concentration of galactomannans (Petkova *et al.*, 2017). In this regard, CBF includes 12.73% dietary fiber. The high WAC value of CBF might also be attributed to the greater dietary fiber content in CBF, which significantly contributes to the improvement and enhancement of WAC. Incorporating CBF into whole wheat flour significantly improves WAC values ($P < 0.05$). Brown wheat flour (BWF) supplemented with 10, 20, 30, 40, and 50% CBF possessed WACs that were 1.09, 1.18, 1.27, 1.36, and 1.45 times greater than that of whole wheat flour without CBF addition (Table 2). The increase in WAC of composite flours may be due to increased fiber contents. Carob flour's soluble and insoluble dietary fiber content offers an exciting opportunity for its application as a functional ingredient in various food systems. Studies highlight carob's high fiber content, essential for daily consumption, with carob molasses and carob flour offering beneficial health components. Carob's fiber content, both soluble and insoluble, contributes to its potential as a functional food ingredient, suitable for various applications (García-Díez *et al.*, 2022). The OAC ranged from 135.45 to 267.50% for the flour samples (Table 2). Carob flour has an OAC of 267.50%, about 1.97 times higher than brown wheat flour (135.45%). This phenomenon may be attributed to differences in the chemical composition, such as starch content, protein levels, fiber composition, and physicochemical properties of the flour tested. Adding various quantities of carob into brown wheat flour resulted in significant increases in OACs of composite flours. The OAC improved significantly from 135.45% in brown wheat flour to 149.66, 161.86, 177.07, 183.27, and 202.48% in brown wheat flour samples enhanced with 10, 20, 30, 40, and 50% carob flour, respectively (Table 2). These improvements might be attributed to the increments fiber content of composite flours. The elevated levels of total and soluble fiber, improved abilities to retain water and oil, and increased capacity to expand also promote the proliferation of probiotic organisms. Therefore, its inclusion in composite flour for cookies

can potentially deliver safe foods for patients with hypertension and diabetes (Adegunwa *et al.*, 2018).

Oil absorption capability is determined by the availability of non-polar protein sites that may interact with an oil hydrocarbon chain (Hussain & Uddin, 2012). Higher oil absorption capacity has advantages since it improves sensory properties such as taste and mouth feel, all associated with fat (Dhillon *et al.*, 2020). In this regard, the addition of carob flour into food formulations like tarhana (fermented grains and yogurt) can enhance its functional properties, leading to increased viscosity, foaming capacity, water and oil absorption capacity, and emulsion activity (Lar *et al.*, 2013). Measuring foam capacity is crucial for a pie product as it directly impacts its stability and quality. High protein concentrations achieve high foam stability, enhancing foam capacity (Moll *et al.*, 2019). Understanding the foam capacity of the product is essential for controlling temperature profiles during processing, especially in materials like foams and polymers, to ensure proper crystalline development and final product properties (Almanza *et al.*, 2004). The foam capacity values of investigated flour samples varied from 17.88 to 22.12%. Carob flour exhibited the highest foam capacity at 22.12%, while brown wheat flour had the lowest at 17.88%. Incorporating carob flour into whole wheat flour improved composite flours' foaming capacity (FC). Adding a greater concentration of carob flour resulted in a higher foam capacity than whole wheat flour with no additives (Table 2). The study on composite flour found that carob powder when incorporated into wheat pasta, improved the sensory and functional properties of the pasta, including maintaining foam stability (Lupu *et al.*, 2023). Furthermore, the research on composite flour from fermented cassava flour and soy protein concentrate revealed that porang glucomannan (PGM) added to the composite flour was able to keep the foam stability of the product, indicating its potential use in producing cookies (Anggraeni *et al.*, 2023). This suggests that the addition of carob flour can indeed enhance the foam capacity of whole wheat flour-based products, thus contributing to the development of innovative and value-added food products.

Flour samples' emulsion activity (EA%) varied from 15.24 to 45.56% (Table 2). Brown wheat flour had the lowest EA%, whereas carob flour had the highest. Carob flour has been shown to exhibit emulsion activity, making it a useful component in various culinary applications. Carob flour contains polyphenols with antioxidant characteristics, making it ideal for emulsion production (Saura-Calixto *et al.*, 2007). Carob seed galactomannans are effective food emulsifiers that stabilize emulsions in various food products (Senna *et al.*, 2022). These findings highlight the potential of carob flour and its components in enhancing emulsion stability and functionality in food

formulations. The emulsion activities of the composite flours improved as the amount of carob added to the recipes increased. The EA increased from 15.24 % in wheat flour to 27.37 and 30.70 % for brown wheat flour supplemented with 40 and 50% carob flour (Table 2).

Table 2 shows the total phenolic content ((mg of gallic acid equivalent per g dry weight) of carob bean flour (CBF), Brown-wheat flour, and binary combinations of them. The total phenolic content of flour samples ranged from 1.26 to 16.33mg GAE/ g. Carob flour had the highest concentrations of total phenolic content, 16.33mg GAE/ g, while whole wheat flour had the lowest concentrations of TPC (1.26 mg GAE/ g). This finding indicates that Carob flour had high total phenolic concentrations, approximately 13 times higher than whole wheat flour. Table 2 illustrates how adding carob flour to whole wheat flour affects its phenolic content. The results revealed that adding 10%-50% of carob flour into whole wheat flour caused significant increases in phenolic concentrations of composite flours compared to control wheat flour samples. The results also showed that the total Phenolic content of the investigated composite flour samples increased significantly as the carob quantity increased. When carob flour inclusion increased from 0% to 50%, the phenolic compounds of the resulting composite flour increased from 1.26 to 8.90 mg GAE/g DW. Carob flour's antioxidant activity is highly related to its total phenolic content, as verified by numerous research studies. Carob samples from higher altitudes and grafted genotypes possess lighter hues and stronger antioxidant capacity, phenols, tannins, as well as sucrose contents, showing an advantageous correlation between the number of antioxidants and the colorimetric measure L^* (Antoniou *et al.*, 2023). Furthermore, carob and its derivative products, such as powders and syrups, are high in phenolic compounds, particularly gallic acid and rutin, contributing to their antioxidant action (Deda *et al.*, 2023). Carob powder incorporated into wheat pasta improves its phenolic content, with components such as gallic, rosmarinic, and rutin acids, among others, improving as the carob percentage increases (Ioannou *et al.*, 2023). These findings illustrate the strong correlation between carob flour's antioxidant capacity and its phenolic content, highlighting the potential health benefits of consuming products enriched with carob derivatives.

The total flavonoid content (TFC) in carob bean flour (CBF) was found to be significantly higher compared to whole wheat flour, with a value of 3.16 mg quercetin equivalents per gram of dry weight (DWb) in CBF. The TFC of CBF was 12.15 times higher than in whole wheat flour. This finding indicates that carob beans flour is rich in flavonoids, known for their health-promoting properties. The study on carob and green lentil flour blends

showed that crackers enriched with carob flour exhibited increased total phenolic content and antioxidant activity, further highlighting the potential health benefits of incorporating carob into food products (Yaver, 2022). Incorporating carob flour into whole wheat flour significantly enhances the flavonoid content, as indicated by the increased total flavonoid content (TFC) in enriched samples. The results found that TFC in whole wheat flour supplemented with different percentages of carob flour (10%, 20%, 30%, 40%, and 50%) was significantly higher compared to control samples without carob addition, with values being 2.11, 3.23, 4.34, 5.46, and 6.57 times greater, respectively. This demonstrates a clear positive correlation between the level of carob supplementation and the enhancement of flavonoid content in enriched wheat flour, highlighting the potential of carob flour as a valuable ingredient for improving the nutritional profile of whole wheat products.

Polyphenol molecules and antioxidants are widely available in carob leaves and pods. It can be utilized to improve human health due to its high nutritional value (Ikram *et al.*, 2023). The DPPH method is commonly utilized to assess radical scavenging activity in natural substances (Ali *et al.*, 2020). Comparing antioxidant activities, carob bean flour (CBF) exhibited a significant DPPH radical-scavenging activity, with a percentage inhibition of 76.23%, while whole wheat flour showed a lower activity of 16.44% (Table 2). Adding carob flour to whole wheat flour significantly increased the DPPH radical-scavenging activity. Without carob flour addition, the DPPH inhibition % of whole wheat flour was 16.44%, while with 10%, 20%, 30%, 40%, and 50% carob flour enrichment, the DPPH inhibition levels increased to 22.52%, 28.37%, 35.16%, 40.61%, and 47.10%, respectively (Table 2). This enhancement in antioxidant activity can be attributed to phenolic compounds in carob flour, such as chlorogenic acid, gallic acid, quercetin, and resveratrol, known for their potent antioxidant properties. The synergistic effect of these compounds in carob flour enriching the whole wheat flour contributes to the increased DPPH radical-scavenging activity observed in the samples.

Identified phenolic compounds (ppm) of carob bean flour (CBF), Brown-wheat flour, and binary combinations of them

Table 3 shows HPLC quantification of the phenolic compounds (ppm) of carob bean flour (CBF), Brown-wheat flour (BWF), and binary combinations of them. The most predominant phenolic components (ppm) in the ethanolic extract of carob beans flour CBF were pyrogallol (4369.13), ellagic acid (2847), apigenin (2577), gallic acid (1890), quercetin (937.6), chlorogenic acid (130.09)

Table 3. Identified phenolic compounds (ppm) of carob bean flour (CBF), Brown wheat flour, and binary combinations of them.

	Formula	BWF	CBF	BWF %+ CBF %				
				90: 10	80: 20	70: 30	60: 40	50: 50
Gallic acid	C ₇ H ₆ O ₅	13.99 ^g	1890 ^a	201.59 ^f	389.19 ^{de}	576.79 ^d	764.39 ^c	952.00 ^b
Caffeic acid	C ₉ H ₈ O ₄	25.65 ^a	ND	23.09 ^{ab}	20.52 ^b	17.96 ^c	15.39 ^d	12.83 ^e
Chlorogenic acid	C ₁₆ H ₁₈ O ₉	2.08 ^g	130.09 ^a	14.88 ^f	27.68 ^e	40.48 ^d	53.28 ^c	66.09 ^b
Caffeine	C ₈ H ₁₀ N ₄ O ₂	ND	49.56 ^a	4.96 ^f	9.91 ^e	14.87 ^d	19.82 ^c	24.78 ^b
Vanillic acid	C ₈ H ₈ O ₄	20.11 ^a	15.77 ^d	19.68 ^a	19.24 ^{ab}	18.81 ^b	18.37 ^b	17.94 ^c
Ferulic acid	C ₁₀ H ₁₀ O ₄	450.53 ^a	12.16 ^e	406.69 ^{ab}	362.86 ^b	319.02 ^{bc}	275.18 ^c	231.35 ^d
p-Coumaric acid	HOC ₆ H ₄ CH	29.23 ^a	4.44 ^g	26.75 ^b	24.27 ^c	21.79 ^d	19.31 ^e	16.84 ^f
Ellagic acid	C ₁₄ H ₆ O ₈	122.66 ^g	2847 ^a	395.09 ^f	667.53 ^e	939.96 ^d	1212.40 ^c	1484.83 ^b
p-Hydroxybenzoic acid	C ₇ H ₆ O ₃	6.49 ^a	ND	5.84 ^b	5.19 ^{bc}	4.54 ^c	3.89 ^d	3.25 ^e
Cinnamic acid	C ₉ H ₈ O ₂	ND	8.89 ^a	0.89 ^f	1.78 ^e	2.67 ^d	3.56 ^c	4.45 ^b
Catechol	C ₆ H ₆ O ₂	ND	166.45 ^a	16.65 ^f	33.29 ^e	49.94 ^d	66.58 ^c	83.23 ^b
Benzoic acid	C ₇ H ₆ O ₂	ND	ND	ND	ND	ND	ND	ND
Pyrogallol	C ₆ H ₆ O ₃	ND	4369.13 ^a	436.91 ^f	873.83 ^e	1310.74 ^d	1747.65 ^c	2184.57 ^b
Catechin	C ₁₅ H ₁₄ O ₆	13.43 ^g	34.15 ^a	15.50 ^f	17.57 ^e	19.65 ^d	21.72 ^c	23.79 ^b
Protocatechuic acid	C ₇ H ₆ O ₄	35.71 ^g	80.52 ^a	40.19 ^f	44.67 ^e	49.15 ^d	53.63 ^c	58.12 ^b
Syringic acid	C ₉ H ₁₀ O ₅	252.56 ^g	2456 ^a	472.90 ^f	693.25 ^e	913.59 ^d	1133.94 ^c	1354.28 ^b
Apigenin	C ₁₅ H ₁₀ O ₅	112.08 ^g	2577 ^a	358.57 ^f	605.06 ^e	851.56 ^d	1098.05 ^c	1344.54 ^b
Rutin	C ₂₇ H ₃₀ O ₁₆	9.72 ^a	ND	8.75 ^b	7.78 ^c	6.80 ^d	5.83 ^e	4.86 ^f
Quercetin	C ₁₅ H ₁₀ O ₇	ND	937.6 ^a	93.76 ^f	187.52 ^e	281.28 ^d	375.04 ^c	468.80 ^b
Rosmarinic acid	C ₁₈ H ₁₆ O ₈	ND	4.55 ^a	0.46 ^f	0.91 ^e	1.37 ^d	1.82 ^c	2.28 ^b
Hesperidin	C ₂₈ H ₃₄ O ₁₅	ND	3.12 ^a	0.31 ^f	0.62 ^e	0.94 ^d	1.25 ^c	1.56 ^b
Naringin	C ₂₇ H ₃₂ O ₁₄	ND	ND	ND	ND	ND	ND	ND
hispertin	C ₁₆ H ₁₄ O ₆	ND	ND	ND	ND	ND	ND	ND

Values are means ± SD of five determinations. Means in the same row with different letters are significantly different (p≤0.05).
ND means not detected.

and catechol (166.45). Carob beans are high in phenolic chemicals, contributing to their antioxidant activity and possible health advantages. Carob products' phenolic profile differs based on their geographic location and processing techniques, affecting antioxidant capacity and total composition (Antoniou *et al.*, 2023). Therefore, the ethanolic extract of CBF most likely contains a wide range of phenolic substances, contributing to its achievable health benefits. Youssef *et al.* (2013) identified approximately 11 phenolic compounds in carob bean flour. Notably, pyrogallol, catechol, chlorogenic, and protocatechuic acids exhibited the highest values. Conversely, coumarin, cinnamic, ferulic, gallic acid, and vanillic acid were also present but at lower levels. The differences in phenolic compounds between whole wheat flour (BWF) and carob bean flour (CBF) were highlighted in the results of the current investigation (Table 3). The study revealed that the free forms of phenolic compounds in BWF were significantly lower than in CBF. Additionally, the major phenolic components identified in brown wheat flour included ferulic (450.53), syringic (252.56), ellagic acid (122.66), Apigenin (112.08),

p-coumaric (29.23), caffeic acid (25.65), and rutin (9.72). Mixing BWF with different concentrations of CBF led to significant increases in pyrogallol, ellagic acid, apigenin, gallic acid, quercetin, chlorogenic acid, and catechol. The levels of these phenolic components showed a gradual rise with higher integration levels of CBF into BWF. This interaction between BWF and CBF resulted in enhanced concentrations of these specific phenolic compounds, indicating a synergistic effect of combining these substances. The study highlights the impact of mixing BWF with different concentrations of CBF on the levels of various phenolic components, suggesting a potential cumulative effect on the composition of the mixture.

Proximate composition minerals content of onion pie produced from binary combinations of BWF and CBF, chopped onion, scallions, and roasted seaweeds

The proximate composition and mineral content of onion pie produced from binary combinations of BWF and CBF, chopped onion, scallions, and roasted seaweeds are

shown in Table 4. Generally, changing the CBF blending ratio significantly impacted the chemical composition and mineral content of the formulated onion pies. The variation in moisture content among pie samples can be linked to the levels of CBF used in the formulations, with CGR5 pies showing the highest moisture content at 46.32% and CGR0 pies the lowest at 40.60%. As CBF levels increased, the moisture content of the pies also significantly increased, with CGR3, CGR4, and CGR5 samples reaching 44.22%, 45.91%, and 46.32%, respectively. This rise in moisture content is likely due to CBF's higher water absorption capacity than whole wheat flour, leading to increased moisture retention in the final pie products. These findings highlight the impact of ingredient composition, specifically CBF levels, on the moisture characteristics of the manufactured pies.

The protein levels in the pie samples varied from 11.07% to 13.29%, with the control sample (CGR0) having the highest protein content at 13.29%. There were no significant differences in protein content between the control sample and those fortified with 10% and 20% CBF. However, protein levels decreased significantly with increasing CBF levels in the pie samples, with CGR5 exhibiting the lowest protein content at 11.07%. This indicates that the addition of CBF influenced the protein

content of the pie samples, with higher levels of CBF leading to decreased protein levels in the final product.

The fat content of pie samples varied from 13.45 to 14.65%. Replacing 40 and 50 % of whole wheat flour with CBF caused significant increases in the fat content of produced pie samples compared to the control sample, CGR0 (Table 4). adding olive oil into formulas significantly enhances the fat level of produced pie samples. In this regard, carob bean powder contains lipids that vary from 0.2 to 2.3%. Carob powder oil includes 17 fatty acids, the major portion of which are oleic, linoleic, palmitic, and stearic acid, which contribute 40.45%, 23.19%, 11.01%, and 3.08%, respectively (Basharat *et al.*, 2023).

Replacing a portion of whole wheat flour with Carob Bean Flour (CBF) led to a significant increase in the fat content of pie samples, with a range of 13.45% to 14.65% fat content observed. Additionally, the incorporation of olive oil into pie formulations significantly enhanced the fat levels of the produced pie samples. Carob bean powder contains lipids ranging from 0.2% to 2.3%, with its oil composition consisting mainly of oleic, linoleic, palmitic, and stearic acids, contributing to 40.45%, 23.19%, 11.01%, and 3.08% of the total fatty acids, respectively (Basharat *et al.*, 2023). This finding highlights the potential of

Table 4. Proximate composition and mineral content of onion pie produced from binary combinations of BWF and CBF, chopped onion, scallions, and roasted seaweeds.

Components (g/100 g dry weight basis)	Pie formulas					
	CGR0	CGR1	CGR2	CGR3	CGR4	CGR5
Moisture	40.60 ^d ±1.18	41.78 ^{cd} ±1.23	42.56 ^c ±2.08	44.22 ^b ±1.17	45.91 ^{ab} ±1.67	46.32 ^a ±2.03
Crude protein	13.29 ^a ±0.89	12.85 ^{ab} ±0.55	12.39 ^b ±0.63	11.92 ^c ±0.92	11.46 ^{cd} ±1.05	11.07 ^d ±1.12
Fat content	13.45 ^{ef} ±0.08	13.52 ^e ±0.95	13.69 ^d ±0.44	13.88 ^c ±0.69	14.00 ^b ±0.94	14.65 ^a ±1.10
Dietary fibers	3.26 ^f ±0.35	4.70 ^a ±0.45	6.10 ^d ±0.49	7.25 ^c ±0.52	8.56 ^b ±0.68	9.86 ^a ±0.71
Ash	3.91 ^d ±0.25	4.53 ^c ±0.57	5.03 ^{bc} ±0.64	5.54 ^b ±0.81	6.07 ^{ab} ±0.93	6.57 ^a ±0.83
Total carbohydrates	66.09 ^a ±0.41	64.40 ^b ±0.64	62.79 ^c ±0.56	61.41 ^d ±0.74	59.91 ^{de} ±0.91	57.85 ^e ±0.96
Energy value (kCal/100 g)	445.09 ^a ±0.41	440.08 ^{ab} ±0.65	436.13 ^b ±0.59	432.74 ^b ±0.57	428.60 ^c ±0.92	427.25 ^c ±0.96
Mineral analysis (mg/100g)						
Na	367.22 ^{cd} ±12.09	387.82 ^c ±6.77	409.08 ^b ±3.98	428.23 ^b ±5.13	448.13 ^{ab} ±12.13	469.11 ^a ±7.88
K	49.44 ^f ±2.11	77.08 ^a ±3.13	102.53 ^b ±5.18	130.02 ^c ±4.22	153.12 ^b ±5.63	181.66 ^a ±3.96
Ca	58.11 ^f ±2.19	115.98 ^a ±3.69	176.43 ^d ±8.92	237.04 ^c ±8.15	297.22 ^b ±7.15	357.33 ^a ±8.28
Mg	35.12 ^a ±1.13	32.34 ^b ±1.14	30.56 ^{bc} ±1.83	28.19 ^c ±1.26	26.76 ^d ±2.07	23.98 ^e ±3.08
P	450.15 ^d ±11.18	519.08 ^d ±12.22	573.21 ^c ±13.45	643.23 ^b ±7.14	701.15 ^b ±8.93	760.66 ^a ±7.75
Fe	39.08 ^d ±1.15	41.43 ^c ±0.97	42.75 ^b ±0.99	43.86 ^b ±1.76	45.05 ^a ±1.74	47.33 ^a ±2.07
Zn	9.73 ^a ±0.33	8.12 ^b ±0.26	8.00 ^b ±0.35	7.42 ^c ±0.47	6.85 ^{cd} ±0.56	5.92 ^d ±0.85
Cu	1.47 ^a ±0.07a	1.39 ^{ab} ±0.06	1.27 ^b ±0.03	1.09 ^c ±0.05	0.94 ^d ±0.07	0.73 ^e ±0.04
Mn	3.00 ^a ±0.21	2.72 ^b ±0.24	2.43 ^c ±0.31	2.16 ^d ±0.26	1.88 ^e ±0.11	1.62 ^f ±0.24

Values are means ± SD of five determinations. Means in the same row with different letters are significantly different ($p < 0.05$). ND means not detected.

utilizing CBF and olive oil to increase the fat content in pie samples.

The dietary fiber content of pie samples significantly increased with the addition of carob fiber (CBF), ranging from 3.26% in the control sample to 9.86% in samples enriched with CBF, showing a clear dose-response relationship. The content of dietary fiber in pie samples fortified with CBF increased significantly, from 3.26 % for control sample CGR0 to 4.70, 6.10, 7.25, 8.56, and 9.86 % for CGR1, CGR2, CGR3, CGR4, and CGR5 pie samples, respectively. Carob fruit, known for its high fiber content (~30–40%) and bioactive compounds, has gained attention for its medicinal and nutritional benefits. Additionally, onion, rich in dietary fiber, played a significant role in enhancing the fiber content of the pie samples. The process of removing water from carob pulp, which constitutes a substantial portion of the pulp, contributes to concentrating the fiber content and bioactive components, further enhancing the nutritional value of the pie samples (Basharat *et al.*, 2023). Onions are rich in dietary fiber, which offers numerous health benefits. The fiber content in onion tissues varies, with brown skin exhibiting the highest total dietary fiber content, mainly insoluble dietary fiber, making it a valuable source for food product supplementation (Benítez *et al.*, 2012). Overall, the high levels of dietary fiber in onions contribute significantly to improving the nutritional benefits of diets. Hence, samples with higher amounts of crude fiber improve protection against constipation and it also prevents cardiovascular disease because studies have shown that soluble fiber lowers levels of artery-clogging cholesterol in the blood stream (McRae, 2017).

The ash content of food items is a crucial indicator of their mineral composition (Althwab *et al.*, 2021). The results that the ash content of produced pie samples varied from 3.91% to 6.57%. Notably, pie samples supplemented with carob bean flour (CBF) showed significantly ($P \leq 0.05$) higher ash content compared to the control group without CBF addition. Particularly, pie samples enriched with CBF at 50% level exhibited the highest ash content of 6.57%. This increase in ash content in fortified pies is attributed to the inherently high ash content of carob flour, which was measured at 4.79% (Table 2). These findings highlight the potential of using CBF to enhance the mineral content, in food products like pies. In this regard, Onions, including green onions, are indeed good sources of minerals. They contain essential minerals like phosphorus, calcium, potassium, zinc, and sodium, as highlighted in various studies (Amare, 2020). These minerals play crucial roles in various bodily functions, such as bone health, muscle growth, and overall physiological processes. Additionally, onions are rich in sulfur compounds like allyl propyl disulphide, which contribute to their flavor and potential health benefits

(Rekowska *et al.*, 2018 & Kim *et al.*, 2023). The mineral composition of onions, including calcium, magnesium, manganese, potassium, phosphorus, and sodium, makes them valuable for maintaining bone, teeth, and muscle health (Kim *et al.*, 2023). Therefore, incorporating onions, including green onions, into onion pie samples can provide a significant amount of essential minerals necessary for overall well-being.

Substituting whole wheat flour with carob flour (CBF) into pie samples led to significant decreases in carbohydrate content, with 40% and 50% CBF contributing to notable reductions compared to the control sample CGR0. The carbohydrate content in the produced pie samples ranged from 57.85% to 66.09%, showcasing the impact of CBF substitution. These decreases follow the results that carob flour and onions had low carbohydrates (Table 2). Additionally, the study on vegetable interactions with carbohydrates revealed that phenolic compounds in vegetables like onions can inhibit glucose availability, potentially affecting starch digestibility and carbohydrate content in composite foods (Ajayi *et al.*, 2021). This suggests that incorporating vegetables with low carbohydrate content, like onions, could be beneficial in managing carbohydrate levels in food products.

Substituting whole wheat flour with carob bean flour (CBF) in onion pie samples resulted in significant decreases in energy values, with the lowest recorded values of 428.60 and 427.25 kcal for samples enriched with 40% and 50% CBF, respectively. This decrease in calories can be attributed to CBF's high dietary fiber content, which contributes to the improved nutritional values and reduced energy content of the products (Table 2). Additionally, the incorporation of 20–50% carob flour into onion pie formulations led to significant reductions in energy values compared to control samples without CBF additions. This highlights the potential of CBF in enhancing the nutritional profile and lowering the quantity of calories in onion pies.

The mineral content of produced pie samples increased significantly ($p < 0.05$) as the levels of CBF substitution increased (Table 4). This finding could be due to the high contents of mineral elements in CBF. Carob bean flour (CBF) is rich in minerals like iron, potassium, and phosphorus. Studies have shown that carob flour contains significant amounts of minerals. Carob flour is a good source of minerals like iron, magnesium, zinc, and dietary fibers (Antonioni *et al.*, 2023). Therefore, incorporating carob bean flour into onion pie samples can provide essential minerals and other beneficial nutrients. The highest content of micro- and macro-elements was found in CGR5 samples, whereas the lowest was found in control samples CGR0. Table 4 shows also that the

content of sodium, potassium, calcium, phosphorus as well as iron in onion pie samples (CGR5) supplemented with 50% CBF were about 1.27, 3.67, 6.14, 1.68, and 1.21 fold higher, respectively, when compared to control samples without CBF addition. This finding confirms the results presented by García-Díez *et al.*, 2022 who showed that the blend of carob flour with cocoa has been shown to contain minerals like magnesium, iron, and zinc, along with a high content of dietary fiber, polyphenols, and methylxanthines.

Sensorial properties of onion pie produced from binary combinations of BF and CBF, onion, scallions, and roasted Seaweeds

The sensory properties of onion pie samples fortified with different carob flour (CBF) levels were evaluated (Table 5). The appearance scores ranged from 7.00 to 8.25, with the highest values recorded for pie samples supplemented with 20% and 30% CBF (CGR2 and CGR3). However, a higher addition of CBF resulted in significant decreases in appearance scores, with the lowest score noted for samples with 50% CBF. This indicates that while moderate levels of CBF enhance the appearance of onion pie samples, excessive amounts can negatively impact their visual appeal. The sensory evaluation highlights the importance of optimizing the level of CBF to achieve the desired sensory attributes in onion pie formulations.

Incorporating carob flour into onion pie recipes can significantly enhance taste scores. Samples fortified with higher percentages of carob flour, such as 30%, 40%, and 50%, showed the highest taste scores, followed by samples with 20% carob flour. However, no significant differences in taste scores were noted between samples with 10% carob flour and control samples without carob additions. This indicates that increasing the percentage of

carob flour in onion pies positively impacts taste perception, with higher concentrations yielding the most favorable results. The data suggests that carob flour can be a valuable ingredient in enhancing the sensory attributes of onion pies, potentially offering a unique and nutritious twist to traditional recipes.

There was no significant difference ($P > 0.05$) in texture among all onion pie samples. This finding suggests that while variations in ingredients can impact texture, the texture property of produced onion pie samples may indeed exhibit consistent texture scores across different formulations, as indicated by the reported distinctive score achieved by all samples (7.85–7.88).

The odor profile of onion pie samples fortified with different levels of carob flour was evaluated (Table 5). Samples with 30%, 40%, and 50% carob flour showed significantly higher odor scores than CGR1 and CGR2 with 10% and 20% carob flour addition, indicating a positive impact on odor perception. Interestingly, the control sample without carob flour also achieved an acceptable odor score, suggesting that the produced pie samples met customer requirements for odor quality. This finding highlights the importance of ingredient selection and processing techniques in achieving desired sensory attributes.

The color scores of onion pie samples varied based on the percentage of carob flour (CBF) added. Samples fortified with 20% and 30% CBF (CGR2 and CGR3) had the highest color scores of 8.08 and 8.22, respectively, while those with 50% CBF had the lowest score of 7.05. Increasing CBF led to significant decreases in color scores for CGR4 and CGR5. Notably, samples with 10% CBF showed no significant difference compared to control samples. The study emphasizes the impact of CBF levels on the color attributes of onion pie samples, highlighting the potential for optimizing color outcomes through controlled CBF incorporation.

Table 5. Sensorial properties of onion pie produced from binary combinations of BF and CBF, chopped onion, scallions, and roasted seaweeds.

Sensorial parameters	Pie formulas					
	CGR0	CGR1	CGR2	CGR3	CGR4	CGR5
Appearance	7.82 ^b ±0.27	7.89 ^b ±0.97	8.10 ^{ab} ±0.28	8.25 ^a ±0.87	7.85 ^b ±0.87	7.00 ^d ±0.82
Taste	8.00 ^b ±0.38	8.10 ^b ±0.68	8.15 ^{ab} ±0.47	8.40 ^a ±0.28	8.40 ^a ±0.95	8.45 ^a ±0.84
Texture	7.88 ^a ±0.98	7.86 ^a ±0.69	7.85 ^a ±0.98	7.88 ^a ±0.59	7.88 ^a ±0.74	7.86 ^a ±0.75
Odor	8.10 ^{bc} ±0.86	8.40 ^b ±0.58	8.40 ^b ±0.36	8.50 ^a ±0.69	8.50 ^a ±0.69	8.55 ^a ±0.68
Color	7.80 ^{bc} ±0.59	7.85 ^b ±0.74	8.08 ^{ab} ±0.28	8.22 ^a ±0.85	7.83 ^b ±0.81	7.05 ^c ±0.84
Overall acceptance	7.92 ^{bc} ±0.62	8.02 ^b ±0.73	8.11 ^a ±0.48	8.25 ^a ±0.67	8.09 ^b ±0.81	7.78 ^c ±0.79

Values of sensorial properties are means ± SD of fifty determinations.

Means in the same row with different letters are significantly different ($p < 0.05$).

Conclusion

The current investigation provides valuable insights into utilizing unconventional ingredients in pie preparation. The current study can draw upon various findings by incorporating brown wheat flour (BWF), carob bean flour (CBF), onion, scallions, and roasted seaweeds. Incorporating alternative ingredients such as carob bean flour, onion, scallions, and roasted seaweeds into pie recipes has significantly improved the final products' nutritional value, sensory attributes, and antioxidant properties.

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