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FUNCTIONAL, NUTRITIONAL, AND SENSORY QUALITY OF BREAD PRODUCED FROM WHEAT-CARROT-DATE (*PHOENIX DACTYLIFERA* L.) COMPOSITE FLOURS

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composite flour, carrot flour, date flour, wheat bread, quality evaluation

ABSTRACT

This study investigated the functional, nutritional, physical, and sensory properties of bread produced from wheat-carrot-date composite flours. Carrot roots and date fruits were processed into flours. Wheat flour was progressively substituted with carrot flour (0–25%) while date flour was fixed at 10%, generating four composite flours (80/10/10, 75/15/10, 70/20/10, and 65/25/10 wheat/carrot/date). Wheat flour (100/0/0) was used as a control. Bread samples were produced from each composite flour and the control flour (100% wheat flour). Analysis of the functional properties of the flours as well as the physical, proximate, and sensory properties of bread samples were performed using standard methods. Results for functional properties of the flours showed decreasing bulk density (0.82–0.65 g/cm³) and swelling index (7.45–4.45), alongside increasing oil absorption capacity (0.77–1.31 g/g) and water absorption capacity (4.60–6.60 g/g) with higher carrot inclusion. In bread samples, physical properties such as loaf height declined from 10.95 to 3.95 cm, loaf volume from 4.73 to 2.47 cm³, and specific volume from 1.10 to 0.48 cm³/g, while loaf weight increased from 231.9 to 241.9 g as carrot flour increased. Proximate analysis of the bread samples indicated rising moisture (21.45–29.95%), fiber (0.14–0.63%), and ash (0.15–1.70%) contents, with concomitant reductions in protein (15.35–8.45%) and fat (6.76–3.54%) as the proportion of carrot flour increased. Sensory evaluation revealed that 80/10/10 bread sample achieved the highest overall acceptability (8.60), whereas higher substitution levels significantly reduced preference.

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ФУНКЦИОНАЛЬНЫЕ, ПИТАТЕЛЬНЫЕ И ОРГАНОЛЕПТИЧЕСКИЕ СВОЙСТВА ХЛЕБА ИЗ СМЕШАННОЙ МУКИ ИЗ ПШЕНИЦЫ-МОРКОВИ-ФИНИКОВ (*PHOENIX DACTYLIFERA* L.)

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КЛЮЧЕВЫЕ СЛОВА:
смешанная мука, морковная мука, финиковая мука, белый хлеб, оценка качества

АННОТАЦИЯ

В данном исследовании изучали функциональные, пищевые и органолептические свойства хлеба, изготовленного из смешанной муки из пшеницы-моркови-фиников. Корнеплоды моркови и плоды фиников были переработаны в муку. Пшеничную муку заменяли морковной мукой в возрастающем количестве (0–25%), тогда как количество финиковой муки было зафиксировано на уровне 10%, что дало четыре рецептуры смешанной муки (пшеница/морковь/финики: 80/10/10, 75/15/10, 70/20/10 и 65/25/10). Пшеничная мука (100/0/0) использовалась в качестве контроля. Были изготовлены образцы хлеба из каждой смешанной муки и контрольной муки (100% пшеничная мука). Изучали функциональные свойства муки, а также физические свойства, приблизительный химический состав и органолептические свойства образцов хлеба, используя стандартные методы. Результаты анализа функциональных свойств муки показали снижение насыпной плотности (0,82–0,65 г/см³) и индекса набухания (7,45–4,45), наряду с повышением маслопоглощающей способности (0,77–1,31 г/г) и водопоглощающей способности (4,60–6,60 г/г) при более высоком уровне введения моркови. В образцах хлеба были понижены такие физические свойства как высота буханки с 10,95 до 3,95 см, объем буханки с 4,73 до 2,47 см³, удельный объем с 1,10 до 0,48 см³/г, в то время как вес буханки увеличился с 231,9 до 241,9 г при увеличении доли морковной муки. Анализ приблизительного химического состава образцов хлеба показал повышение содержания влаги (21,45–29,95%), клетчатки (0,14–0,63%) и золы (0,15–1,70%) с одновременным снижением белка (15,35–8,45%) и жира (6,76–3,54%) по мере увеличения доли морковной муки. При органолептическом анализе образец хлеба 80/10/10 получил наивысшую оценку общей приемлемости (8,60), тогда как более высокие уровни замены существенно снижали предпочтение.

1. Introduction

Bread is one of the most widely consumed baked foods globally and remains a major contributor to daily energy intake across diverse age groups and socio-economic settings. At the same time, consumer expectations around bread are shifting beyond convenience and affordability. Many consumers now look for products that deliver added nutritional value (particularly higher dietary fiber, micronutrients, and naturally occurring bioactive compounds) without sacrificing sensory quality. This has accelerated research interest in composite flour technology and in the use of fruit- and vegetable-derived ingredients to improve the nutritional profile of bakery products, such as bread, while maintaining acceptable loaf characteristics [1]. Composite flour formulations, where

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wheat is partially substituted with nutrient-dense plant materials, are often positioned as a practical strategy to enhance the micronutrient and fiber content of staple baked foods, and to diversify raw material use in a way that supports local value chains. Beyond nutrition, the functional behavior of composite flour (e.g., water absorption capacity, oil absorption capacity, bulk density, swelling properties) strongly influence dough handling, gas retention, crumb structure, and the final texture of baked products. For this reason, evaluating techno-functional properties is central to explaining why a given flour blend produces a particular loaf volume, crumb softness, or sensory outcome [2–4].

Among potential fortifying ingredients, carrots (*Daucus carota L.*) and dates (*Phoenix dactylifera L.*) are especially attractive because they offer complementary nutritional and functional benefits. Carrots are widely recognized as a rich source of carotenoids (including β-carotene) alongside dietary fiber and a spectrum of phenolic compounds [5,6]. When dried and milled into powder, carrot materials can be incorporated into cereal-based foods as a nutritional enhancer. Recent work on carrot-derived ingredients in baked foods shows consistent improvements in antioxidant potential and mineral contribution, although technological changes (such as reduced loaf expansion or altered crumb structure) may occur at higher substitution levels depending on particle size, fiber content, and water competition during dough development [7]. In bread systems specifically, carrot ingredients have been reported to increase the antioxidant capacity of the final product and enrich the bread matrix with bioactive compounds, but the overall impact on bread quality is highly dependent on the inclusion rate and formulation context. For example, studies incorporating carrot-based powders into wheat bread often report improved nutritional attributes but also note that higher inclusion levels can intensify carrot flavor and influence dough properties [8]. These technological trade-offs are important because they directly shape consumer acceptance. In practical terms, carrot fortification tends to improve the "health story" of bread, but it can also shift crumb color and aroma, and it may reduce specific volume if gluten dilution and fiber-driven water binding are not properly managed [9].

Dates, on the other hand, contribute to a different set of advantages that align well with current clean-label and sugar-reduction trends. Date fruit and date-derived powders/pastes provide natural sweetness along with dietary fiber, minerals, and phenolic antioxidants [10]. Importantly, dates have been increasingly discussed as a natural alternative to refined sweeteners, supporting both nutritional enhancement and sustainability narratives through the valorization of second-grade or surplus dates [11]. Reviews of date-based sweetening strategies highlight their potential for reformulating sweet bakery products while adding micronutrients and antioxidant compounds, although formulation must carefully account for changes in moisture dynamics, browning reactions, and texture. Evidence from recent baked-product research supports the use of date powders as functional ingredients capable of contributing dietary fiber and phenolics while acting as natural sweeteners. For instance, investigations using bisr date powder (an early maturity stage) emphasize that date powders can supply flavonoids and antioxidant compounds and may replace refined sugar in formulations, with measurable effects on the chemical, physical, and sensory properties of the final product [12]. While many of these studies focus on biscuits, the underlying formulation principles (water activity control, fiber-driven texture changes, and flavor impacts) remain relevant when adapting date ingredients to bread systems.

From a product development perspective, combining carrot and date ingredients in wheat bread is conceptually promising because the two materials may complement each other: carrots can enrich bread with carotenoids and fiber while contributing an appealing warm crumb color, whereas dates can provide natural sweetness and additional fiber/minerals that may improve overall palatability. However, bread is a structurally sensitive system, and successful fortification is rarely achieved by "adding more nutrients" alone. Wheat dough performance depends on gluten network formation and gas retention during proofing and baking. Any ingredient that competes for water, dilutes gluten, or introduces coarse insoluble fiber can shift the dough's rheology and reduce loaf expansion, unless the blend level and water management are optimized. This is why measuring flour functional properties alongside bread proximate composition, physical quality indices (loaf weight, loaf volume, specific volume), and sensory attributes are necessary to interpret performance scientifically. Despite growing interest in vegetable- and fruit-based fortification, there remains a practical gap in the literature on wheat bread formulated with combined carrot and date ingredients. Many fortification studies report improved nutrient profiles but do not provide an explanation of how functional properties of the flour blend translate into bread structure and acceptability, which limits usefulness for formulation scale-up. In addition, the optimal inclusion range is often product-specific, meaning that the "best" level is the one that provides meaningful nutritional enhancement while maintaining loaf quality and consumer liking. Therefore, the aim of this study was to evaluate bread produced from wheat–carrot–date composite flours by assessing the functional properties of the flour blends and determining how these properties relate to the proximate composition, physical quality characteristics, and sensory acceptability of the resulting breads.

2. Objects and methods

2.1. Objects

Wheat flour, carrots, dates and other ingredients (baking powder, fat/margarine, yeast and salt) were purchased from Modern market Makurdi, Benue State, Nigeria. Portable water was used throughout the experiment. The processing of materials and the experiments were carried out using the facilities and equipment available at the Department of Food Science and Technology Laboratories, Joseph Sarwuan Tarkaa University Makurdi.

2.2. Preparation of date flour

Date flour was prepared following the method described by [13]. Mature date palm fruits were manually sorted to remove damaged fruits, extraneous materials, and adhering debris. The fruits were thoroughly washed under running tap water and manually de-pitted to separate the seeds from the edible pulp. The de-pitted date flesh was then spread in a single layer on stainless steel trays and dried in a hot-air cabinet dryer UN110 (Memmert GmbH Co. KG, Schwabach, Germany) at 70 °C until a constant weight was achieved. The dried date flesh was milled into a fine flour using hammer mill Retsch ZM 200 (Retsch GmbH, Haan, Germany). The resulting flour was passed through a 250 μm mesh sieve to obtain a uniform particle size and to remove coarse fractions. The sieved date flour was immediately packaged in airtight polyethylene bags and stored at ambient temperature until further use to minimize moisture uptake and oxidative deterioration.

2.3. Preparation of carrot flour

Carrot flour was prepared as previously described in [14]. Fresh carrot roots were manually sorted to remove damaged and diseased samples, washed thoroughly under running tap water to eliminate adhering soil and extraneous materials, and peeled using a stainless-steel knife. The peeled carrots were sliced into uniform thickness (approximately 2 mm) using a vegetable slicer. The carrot slices were blanched in hot water at 95 °C for 5 min in the presence of 0.1 % (w/v) sodium metabisulphite to minimize enzymatic browning and color degradation. After blanching, the slices were rapidly cooled in cold water and drained. The blanched carrot slices were then dried in a hot-air cabinet dryer UN110 (Memmert GmbH Co. KG, Schwabach, Germany) at 60 °C for 12 h until a constant weight was attained. Dried carrot slices were milled into powder using hammer mill Retsch ZM 200 (Retsch GmbH, Haan, Germany). The resulting powder was passed through a 500 μm mesh sieve to obtain a uniform particle size. The sieved carrot flour was packaged in airtight polyethylene bags and stored at ambient temperature until further use.

2.4. Production of bread from wheat-carrot-date composite flours

Four composite flour formulations were prepared by partially substituting wheat flour with carrot flour and date powder at different inclusion levels. The control sample (sample A) consisted of 100 % wheat flour. In sample B, wheat flour was substituted with 10 % carrot flour and 10 % date powder, resulting in a formulation containing 80 % wheat flour. Sample C was formulated with 75 % wheat flour, 15 % carrot flour, and 10 % date powder. Sample D contained 70 % wheat flour, 20 % carrot flour, and 10 % date powder, while sample E was formulated with 65 % wheat flour, 25 % carrot flour, and 10 % date powder. These formulations were designed to evaluate the effects of progressively increasing carrot flour substitution at a constant date powder level on the functional properties of the composite flours and the quality attributes of the resulting breads.

Bread samples were produced from the control and the composite flours, using a straight-dough method described by [15] with slight modification. For each batch, the baking formula consisted of 49.26 % wheat flour or 57. 14 % composite flour, 0.99 % of compressed baker's yeast (*Saccharomyces cerevisiae*), 0.49 % of salt, 3.94 % vegetable shortening, and 37.43 % of potable water. Granulated sugar (7.88 %) was added to the mix containing 100 % wheat flour. The dry ingredients (flour, sugar, and salt) were first combined in a mixing bowl to ensure uniform distribution. Baker's yeast was reconstituted in a small portion of the formulation water and allowed to activate before adding to the flour mixture. Vegetable shortening was then incorporated, followed by addition of the remaining water mixing in a Kenwood mixer ModelA 907 D (Kenwood Limited, England) until a smooth and cohesive dough was formed. The dough was kneaded by hand to develop structure and allowed to ferment for 90 min at 28±1 °C. After fermentation, the dough was punched down to expel entrapped gas, scaled into 250 g portions, and molded into loaf shapes. The molded dough pieces were proofed for 90 min at 30 °C and 85% relative humidity. Proofed loaves were baked in a preheated oven Uniscope SM-9053, (Uniscope England) at 250 °C for 30 min. After baking, the loaves were removed from the pans and cooled at room temperature prior to further analyses.

2.5. Analysis of functional properties of wheat-carrot-date composite flour

Packed bulk density (PBD), water absorption capacity (WAC), oil absorption capacity (OAC), and swelling index (SI) of the 100% wheat flour or composite flour were determined following the procedures described by [16].

2.6. Analysis of bread produced from wheat-carrot-date composite flours

Physical properties such as loaf weight, loaf volume, specific loaf volume, and loaf height were determined as previously described in [15]. Proximate properties including moisture, ash, and crude fiber contents were determined using AOAC 2005 method as described by [17] while protein and fat contents were determined according to the AOAC 2005 method using Kjeldahl and Soxhlet extraction, respectively, as described by [16]. The difference method described in [16] was used to calculate carbohydrate content. The bread samples were randomly coded and served to a panel of 30 assessors comprising students and staff. Panelists evaluated the samples for appearance, aroma, taste, mouthfeel, and overall acceptability using a nine-point hedonic scale, in which a score of 9 represented “like extremely” and a score of 1 represented “dislike extremely” as previously described in [18].

2.7. Statistical analysis

All experiments were performed in triplicate, and the data were presented as the mean±SD. Statistical analysis of experimental data was performed using the Statistical Package for Social Sciences (SPSS) 27.0. One-way analysis of variance (ANOVA) was conducted to determine significant differences among sample means, followed by Duncan’s multiple range test to identify specific differences between means [19]. A significance level of $p < 0.05$ was applied for all statistical comparisons.

3. Results and discussions

3.1. Functional properties of wheat-carrot-date composite flour

The functional properties of the composite flours, presented in Table 1, provide an indication of how each blend is likely to behave during mixing, proofing, and baking. This is because parameters such as bulk density, water absorption, oil absorption, and swelling are closely linked to hydration, dough consistency, and texture development in cereal-based products [3].

Table 1. **Functional properties of wheat-carrot-date composite flour**

Таблица 1. **Функциональные свойства смешанной муки из пшеницы-моркови-фиников**

Sample	Bulk density, g/cm^3	OAC, g/g	WAC, g/g	Swell index, %
A (100/0/0)	0.82 ± 0.05^{a}	0.77 ± 0.05^{c}	4.60 ± 0.05^{bc}	7.45 ± 0.05^{b}
B (80/10/10)	0.78 ± 0.05^{ab}	0.86 ± 0.05^{bc}	4.70 ± 0.05^{ab}	6.05 ± 0.05^{d}
C (75/15/10)	0.71 ± 0.05^{bc}	0.87 ± 0.05^{b}	5.40 ± 0.05^{c}	5.75 ± 0.05^{a}
D (70/20/10	0.69 ± 0.05^{c}	1.14 ± 0.05^{a}	5.85 ± 0.05^{a}	5.05 ± 0.05^{c}
E (65/25/10)	0.65 ± 0.05^{c}	1.31 ± 0.05^{bc}	6.60 ± 0.05^{c}	4.45 ± 0.05^{b}

Data are means±SD ($n = 3$). Values with different superscripts within the same column are significantly different ($P < 0.05$).
A (100/0/0): 100% wheat flour, 0% carrot flour, 0% date flour; B (80/10/10): 80% wheat flour, 10% carrot flour, 10% date flour; C (75/15/10): 75% wheat flour, 15% carrot flour, 10% date flour; D (70/20/10): 70% wheat flour, 20% carrot flour, 10% date flour; E (65/25/10): 65% wheat flour, 25% carrot flour, 10% date flour; OAC: oil adsorption capacity; WAC: water adsorption capacity.

Bulk density decreased steadily as wheat flour was progressively substituted with carrot flour at a constant date powder level and range from 0.65 g/cm^3 in sample E (65/25/10) to 0.82 g/cm^3 in sample A (100/0/0). This pattern is consistent with what is commonly observed when higher-fiber, lower-density plant powders are incorporated into wheat flour [20–22]. This is because the blends tend to pack less efficiently due to differences in particle structure, porosity, and compositional makeup. Practically, reduced bulk density can be advantageous from a formulation standpoint because it may improve reconstitution behavior and influence dough handling by changing how quickly the flour hydrates and how the mix develops during kneading [23].

The oil absorption capacity (OAC) ranged from 0.77 g/g in sample A (100/0/0) to 1.31 g/g in sample E (65/25/10). Increased OAC in composite systems is often attributed to greater availability of non-polar binding sites and dietary fiber components, as well as increased surface area/porosity from the added plant ingredient [24]. This is consistent with the increased fiber content observed in this study as wheat flour was progressively substituted with carrot flour at constant date flour level (10%). From an application perspective, higher OAC is generally desirable in baked products because it supports flavor retention and can contribute to a richer mouthfeel by improving lipid binding within the food matrix [25].

Water absorption capacity (WAC) increased with progressive substitution of wheat flour with carrot flour while date powder was held constant at 10%. WAC ranged from 4.60 g/g in sample A (100/0/0) to 6.60 g/g in sample E (65/25/10). This upward trend is consistent with the compositional shift introduced by carrot flour, which contributes substantial dietary fiber (cellulose, hemicellulose, and pectin) and therefore increases the density of hydrophilic functional groups available for water binding. In composite flours, fiber-rich ingredients typically raise WAC because they absorb and retain water within a porous matrix, while also increasing the overall hydration requirement of the blend during dough development [26]. In practical terms, this means that higher-carrot formulations are likely to demand more water to reach a comparable mixing consistency, and if the formulation water is not adjusted, the dough appear stiffer and less extensible as observed in this study. From a bread-making perspective, higher WAC can be a double-edged factor: on one hand, greater water uptake may support improved moisture retention and a softer eating quality during short-term storage; on the other hand, excessive water binding by fiber can reduce the amount of “free” water available for gluten development and starch swelling, which may contribute to changes in gas retention and crumb structure if mixing and proofing conditions remain unchanged. The relatively modest magnitude of change in WAC across the blends suggests that the composite system still retained substantial wheat functionality, but the direction of change showed the role of carrot-derived fiber as the primary driver of hydration behavior when date level is constant. Overall, the WAC trend provides a useful functional explanation for any downstream differences observed in dough handling, loaf volume, and crumb softness across the formulations.

Swelling index decreased consistently as carrot flour substitution increased and ranged from 7.45% in sample A (100/0/0) to 4.45% in sample E (65/25/10). This trend is expected in wheat–vegetable composite systems because swelling is largely driven by the ability of starch granules (abundant in wheat flour) to hydrate and expand [27]. As wheat flour is progressively replaced with carrot flour, the overall starch fraction of the blend is diluted, leaving less starch available to swell. In addition, carrot flour contributes substantial dietary fiber (cellulose, hemicellulose, and pectin), which competes strongly for water and can physically restrict starch granule expansion by creating a more rigid, water-binding matrix. With date powder held constant at 10%, soluble sugars and additional fiber are still present across all composite samples and may further compete for water during hydration, reinforcing the reduction in swelling as carrot flour increases. From a product-quality standpoint, a lower swelling index in higher-carrot blends can translate to reduced starch-driven softness and a tighter crumb structure if formulation water and mixing conditions are not adjusted. This higher substitution levels in composite breads require careful optimization to maintain desirable loaf texture and eating quality.

3.2. Physical properties of bread produced from wheat-carrot-date composite flours

The physical quality indices, presented in Table 2, showed a consistent drop in loaf expansion as wheat flour was progressively replaced with carrot flour while the level of date flour was held constant at 10%. Loaf height dropped markedly from 10.95 cm in sample A (100/0/0) to 3.95 cm in sample E (65/25/10), with bread samples from intermediate blends showing stepwise reductions. A similar pattern was observed for loaf volume and loaf specific volume, which decreased from 4.73 cm^3 in sample A (100/0/0) to 2.47 cm^3 in sample E (65/25/10) and from 1.10 cm^3 in sample A (100/0/0) to 0.48 cm^3 in sample E (65/25/10), respectively. These reductions are due to the well-established effect of gluten dilution in composite bread. Replacing wheat flour with non-wheat plant materials reduces the concentration of gluten-forming proteins (gliadin and glutenin), weakens the viscoelastic dough network, and lowers the capacity of the dough to retain fermentation gases during proofing and baking, ultimately limiting oven spring and loaf expansion [28,29]. Beyond gluten dilution, carrot flour introduces dietary fiber, which can further restrict loaf growth by competing for water, increasing dough consistency, and physically interrupting the continuity of the gluten matrix. This fiber-driven interference is widely reported to reduce gas retention and lead to smaller loaves with tighter structure in fiber-enriched wheat breads [4,30,31]. In the present formulations, the presence of date powder (10% across samples) may provide fermentable sugars that could support yeast activity; however, the dominant structural limitation appears to be the weakened gas-holding network arising from gluten dilution and fiber interference, which ultimately governs loaf height and loaf volume.

Loaf weight increased slightly but consistently from 231.9 g in sample A (100/0/0) to 241.9 g in sample E (65/25/10). This trend is consistent with composite systems where fiber-rich ingredients increase hydration demand and moisture retention. Carrot flour is expected to raise water binding due to its hydrophilic polysaccharides, and higher water retention during baking can yield heavier loaves even when loaf expansion is reduced [4]. In practical terms, reduced loaf expansion combined with higher retained moisture produces a denser loaf. Overall, the physical-property data suggests that if higher carrot inclusion is desired for nutritional reasons, process/formulation optimization (e.g., water adjustment, mixing energy, dough improvers, or hydrocolloids) would likely be required to recover loaf structure and maintain consumer-acceptable bread quality.

Table 2. **Physical properties of bread produced from wheat-carrot-date composite flours**

Таблица 2. **Физические свойства хлеба, изготовленного из смешанной муки из пшеницы-моркови-фиников**

Sample	Loaf height, cm	Loaf volume, cm^3	Loaf weight, g	Specific volume, cm^3/g
A (100/0/0)	10.95 ± 0.05^a	4.73 ± 0.05^a	231.9 ± 0.05^e	1.1 ± 0.05^a
B (80/10/10)	5.45 ± 0.05^b	4.57 ± 0.05^b	238.9 ± 0.05^d	1.07 ± 0.05^a
C (75/15/10)	4.95 ± 0.05^c	3.41 ± 0.05^c	239.9 ± 0.05^c	0.78 ± 0.05^b
D (70/20/10	4.45 ± 0.05^d	2.52 ± 0.05^d	240.9 ± 0.05^b	0.56 ± 0.05^c
E (65/25/10)	3.95 ± 0.05^e	2.47 ± 0.05^d	241.9 ± 0.05^a	0.48 ± 0.05^c

Data are means ± SD ($n = 3$). Values with different superscripts within the same column are significantly different ($P < 0.05$).
A (100/0/0): 100% wheat flour, 0% carrot flour, 0% date flour; B (80/10/10): 80% wheat flour, 10% carrot flour, 10% date flour; C (75/15/10): 75% wheat flour, 15% carrot flour, 10% date flour; D (70/20/10): 70% wheat flour, 20% carrot flour, 10% date flour; E (65/25/10): 65% wheat flour, 25% carrot flour, 10% date flour.

3.3. Proximate composition of bread produced from wheat-carrot-date composite flours

The proximate composition of breads produced from wheat flour partially substituted with carrot flour (at a fixed 10% date powder level) is presented in Table 3. The moisture content of food gives an indication of its stability and keeping quality [32,33]. Moisture increased progressively from 21.45% in sample A (100/0/0) to 29.95% in sample E (65/25/10), indicating that carrot-rich blends retained more water in the baked loaf. This trend is expected because fiber-rich plant materials increase the hydration demand of dough and promote water retention within the crumb matrix, thereby limiting moisture loss during baking as explained earlier. Similar interpretations have been reported in bread enrichment studies, where final bread moisture is closely linked to the amount of water absorbed during mixing and the water-holding behavior of the formulation [3,31].

Protein content decreased steadily from 15.35% in sample A (100/0/0) to 8.45% in sample E (65/25/10). Mechanistically, this reflects a dilution effect: wheat flour contributes the bulk of the protein in standard bread systems, whereas carrot-derived ingredients contain much lower protein levels than wheat and therefore reduce total protein concentration as substitution increases. In addition, the upward shift in moisture can further reduce the apparent protein percentage per 100 g bread. This pattern (declining protein with progressive replacement of wheat by low-protein plant materials) has also been observed in wheat-based blends enriched with carrot pomace and other fruit/vegetable fractions [7].

Like protein, fat content decreased from 6.76% in sample A (100/0/0) to 3.54% in sample E (65/25/10). In composite breads where the shortening/fat added during mixing is held constant as is the case in this study, the measured fat per 100 g bread may still decline when moisture increases and the loaf becomes denser, because proximate values are expressed on a wet basis. A second contributor is ingredient dilution: carrot- and date-derived flours typically do not contribute much lipid relative to wheat-based systems, so increasing substitution tends to reduce the overall lipid fraction attributed to the flour component. Patterns consistent with "substitution-driven" shifts in fat have been documented in wheat flour blends fortified with carrot pomace [7].

As expected, crude fiber increased markedly with carrot inclusion, rising from 0.14% in sample A (100/0/0) to 0.63% in sample E (65/25/10). This reflects the inherently higher dietary fiber content of carrot materials (cellulose/hemicellulose/pectic polysaccharides) and demonstrates that the composite approach achieved nutritional improvement in fiber content compared with the all-wheat control. Similar outcomes (fiber enrichment as wheat is substituted with fruit/vegetable fractions) are widely reported in composite flour studies using carrot-derived ingredients [7].

Ash content increased from 0.15% in sample A (100/0/0) to 1.70% in sample E (65/25/10), indicating increased total mineral contribution with progressive substitution. This is consistent with the fact that many plant and fruit materials contribute higher mineral residues than refined wheat flour, and these minerals are retained through baking because they are not destroyed by heat. Composite bread studies incorporating non-wheat plant ingredients similarly report increases in ash with substitution [34,35]. Carbohydrate (CHO) values remained comparatively stable (54.78–56.15%) across treatments.

3.4. Sensory properties of bread produced from wheat-carrot-date composite flour

Overall, at low carrot flour substitution, sample B (80/10/10) produced the most preferred bread, while higher carrot levels resulted in a progressive decline in sensory quality (Table 4). Appearance scores were high for sample A (100/0/0), the control, which scored 8.46, and sample B (80/10/10), which scored 8.53, but declined sharply with increasing carrot flour, reaching 4.26 in sample E (65/25/10). At low inclusion levels,

Table 3. **Proximate composition of bread produced from wheat-carrot-date composite flour**

Таблица 3. **Приблизительный химический состав хлеба, изготовленного из смешанной муки из пшеницы-моркови-фиников**

Sample	Protein, %	Moisture, %	Fat, %	Fiber, %	Ash, %	CHO, %
A (100/0/0)	15.35 ± 0.05^a	21.45 ± 0.01^d	6.76 ± 0.03^a	0.14 ± 0.05^b	0.15 ± 0.05^d	56.15 ± 0.05^a
B (80/10/10)	13.95 ± 0.05^b	24.95 ± 0.01^c	5.05 ± 0.02^b	0.17 ± 0.03^b	0.99 ± 0.05^c	54.89 ± 0.01^c
C (75/15/10)	11.35 ± 0.05^c	26.45 ± 0.02^b	4.80 ± 0.01^b	0.18 ± 0.03^b	1.11 ± 0.02^b	56.11 ± 0.05^a
D (70/20/10	10.05 ± 0.05^c	29.25 ± 0.01^a	4.01 ± 0.01^c	0.60 ± 0.05^a	1.31 ± 0.03^b	54.78 ± 0.02^c
E (65/25/10)	8.45 ± 0.05^d	29.95 ± 0.04^a	3.54 ± 0.02^d	0.63 ± 0.05^a	1.70 ± 0.04^a	55.73 ± 0.05^b

Data are means ± SD ($n = 3$). Values with different superscripts within the same column are significantly different ($P < 0.05$).
A (100/0/0): 100% wheat flour, 0% carrot flour, 0% date flour; B (80/10/10): 80% wheat flour, 10% carrot flour, 10% date flour; C (75/15/10): 75% wheat flour, 15% carrot flour, 10% date flour; D (70/20/10): 70% wheat flour, 20% carrot flour, 10% date flour; E (65/25/10): 65% wheat flour, 25% carrot flour, 10% date flour; CHO: carbohydrate.

Table 4. **Sensory properties of bread produced from wheat-carrot-date composite flour**

Таблица 4. **Органолептические свойства хлеба, изготовленного из смешанной муки из пшеницы-моркови-фиников**

Sample	Appearance	Taste	Aroma	Mouthfeel	Overall acceptability
A (100/0/0)	8.46 ± 1.74^a	8.26 ± 2.70^a	8.46 ± 2.51^a	8.13 ± 1.83^a	8.53 ± 1.51^a
B (80/10/10)	8.53 ± 1.64^a	8.73 ± 1.45^a	8.53 ± 1.64^a	8.00 ± 1.64^a	8.60 ± 1.50^a
C (75/15/10)	7.93 ± 1.96^b	8.00 ± 2.00^b	8.33 ± 3.61^b	7.40 ± 2.91^b	7.13 ± 1.74^b
D (70/20/10	6.86 ± 1.91^c	7.66 ± 2.04^b	6.93 ± 1.96^b	6.93 ± 1.10^b	5.00 ± 1.00^c
E (65/25/10)	4.26 ± 1.96^d	6.40 ± 1.29^c	5.13 ± 1.50^c	5.60 ± 1.24^c	5.73 ± 1.96^c

Data are means ± SD ($n = 30$). Values with different superscripts within the same column are significantly different ($P < 0.05$).
A (100/0/0): 100% wheat flour, 0% carrot flour, 0% date flour; B (80/10/10): 80% wheat flour, 10% carrot flour, 10% date flour; C (75/15/10): 75% wheat flour, 15% carrot flour, 10% date flour; D (70/20/10): 70% wheat flour, 20% carrot flour, 10% date flour; E (65/25/10): 65% wheat flour, 25% carrot flour, 10% date flour

carrot flour imparted an attractive orange-brown color that enhanced visual appeal. However, at higher substitution levels, reduced loaf height and volume produced a darker, denser crumb that negatively affected appearance. Taste improved slightly at low–moderate carrot levels, with sample B (80/10/10) recording the highest score of 8.73 followed by the control sample A (100/0/0) with a score of 8.26. This reflects the combined effect of natural sweetness from date powder and mild flavor contributions from carrot flour. At higher carrot levels, taste scores declined to 6.40 in sample E (65/25/10), likely due to increased fiber content, which can produce a heavier palate and slight off-flavors in composite breads. Aroma followed a similar trend: samples A (100/0/0) to sample C (75/15/10)) maintained high scores (8.33–8.53), while samples D (70/20/10) and E (65/25/10) showed notable declines with scores of 6.93 and 5.13, respectively. Improved aroma at low substitution may be linked to enhanced Maillard reactions from date sugars and pleasant carrot-derived volatiles. In contrast, weaker gluten structure and denser crumb at higher carrot levels likely limited aroma release. Mouthfeel decreased steadily with increasing carrot flour, dropping from 8.13 in the control to 5.60 in sample E (65/25/10). This reflects gluten dilution and fiber-induced disruption of the dough matrix, which produces a tighter crumb, increased firmness, and reduced elasticity. Overall acceptability score was highest for sample B (80/10/10) (8.60) and declined substantially at higher carrot levels with sample D (70/20/10) and sample E (65/25/10) scoring 5.00 and 5.73, respectively. Collectively, the results showed an optimal enrichment window around 10% carrot flour (with 10% date fixed), where sensory quality is maintained or slightly improved. Beyond this level, texture deterioration and visual darkening dominate consumer perception and drive a marked reduction in acceptability.

4. Conclusion

This study showed that substituting wheat flour with carrot flour (while keeping date powder constant at 10%) measurably changed the techno-functional behavior of the composite flours and, in turn, the quality of the breads produced. Across the formulations (100/0/0 to 65/25/10 wheat/carrot/date), bulk density decreased as carrot flour increased, indicating looser packing of the composite flours, while oil absorption capacity increased, suggesting improved oil-binding potential as more carrot material was incorporated. Water absorption capacity varied only slightly but tended to be higher at the higher-carrot blends, implying greater hydration demand during mixing. Swelling index values also changed across blends. In the baked breads, progressive wheat replacement with carrot flour produced a clear reduction in loaf expansion. Loaf height, loaf volume, and specific volume decreased markedly as carrot flour increased. At the same time, loaf weight increased slightly, which is likely related to higher moisture retention and denser crumb formation in the fiber-enriched breads. Nutritionally, increasing carrot flour generally shifted the bread composition toward higher moisture, fiber, and ash contents, indicating improved water retention and mineral contribution, while key macronutrients changed across formulations. Overall, the proximate results showed that carrot — date enrichment can enhance selected nutritional attributes (notably fiber / ash), but these gains occur alongside quality trade-offs linked to structure and moisture management in the finished loaves. Sensory evaluation supported these trade-offs clearly. Breads produced with low carrot substitution maintained high scores, and the 80/10/10 formulation (sample B) recorded the best overall acceptability. However, higher carrot substitution levels (⩾20–25%) led to notable reductions in consumer ratings, especially for mouthfeel and overall acceptability, consistent with the denser structure and lower loaf expansion observed instrumentally. Taken together, the results suggest an optimal enrichment "window" around 10% carrot flour with 10% date powder (Sample B), where sensory quality is preserved (or slightly improved) while still delivering compositional benefits. If higher carrot inclusion is desired for stronger nutritional positioning, formulation and process adjustments (particularly water optimization and structure-support strategies) will be necessary to recover loaf volume and maintain acceptable texture.

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