Journal of Food Safety and Food Quality
Archiv für Lebensmittelhygiene

J. Food Saf. Food Qual. **2026**; 77(4): 51025
https://doi.org/10.31083/JFSFQ51025

Original Research

Physicochemical and Functional Characterization of Wheat–Whole Cashew Nut Composite Flours and Cookies

Hoang Van Thanh[1], Le Quynh Nhi[2], Tran Thao Nhi[2], Lai Thi Kim Ngan[2], Nguyen Xuan Hoan[3,*], Pham Van Hung[4,5,*]

[1]Center for Experiment and Practice, Ho Chi Minh City University of Industry and Trade, 700000 Ho Chi Minh City, Vietnam
[2]Faculty of Food Science and Technology, Ho Chi Minh City University of Industry and Trade, 700000 Ho Chi Minh City, Vietnam
[3]Faculty of Biology and Environment, Ho Chi Minh City University of Industry and Trade, 700000 Ho Chi Minh City, Vietnam
[4]Department of Food Technology, International University, VNU-HCM, 700000 Ho Chi Minh City, Vietnam
[5]Vietnam National University, 700000 Ho Chi Minh City, Vietnam
*Correspondence: hoannx@huit.edu.vn (Nguyen Xuan Hoan); pvhung@hcmiu.edu.vn (Pham Van Hung)
Academic Editor: Corinna Kehrenberg
Submitted: 14 February 2026 Revised: 10 April 2026 Accepted: 13 May 2026 Published: 8 July 2026

Abstract

Background: The cashew nut processing industry generates large quantities of cashew nut testa annually, which are commonly considered by-products. However, cashew nut testa is a rich source of bioactive compounds with strong antioxidant activity, while cashew kernels possess high nutritional value. This study investigated the incorporation of whole cashew nut flour with testa (CNF) as a partial replacement for wheat flour in cookie formulations. **Methods:** A control cookie prepared with 100% wheat flour (WF) and four CNF-supplemented substitutions (5%, 10%, 15%, and 20%) were developed. Physicochemical analyses of the substituted flours, and physical and textural properties, bioactivities, and sensory of cookies made from the substituted flours were evaluated. **Results:** The results revealed that CNF supplementation significantly influenced viscosity, swelling power, solubility, hardness, and water-related properties. Higher CNF levels were associated with reduced moisture content and softer cookie texture. Nutritional analysis showed progressive increases in lipid, protein, and mineral contents with increasing amounts of CNF. Moreover, total phenolic content (TPC), total flavonoid content (TFC), and total catechin content (TCC) increased markedly, accompanied by enhanced antioxidant activity as indicated by 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging capacity. An *in vitro* digestion model showed that CNF10 was the optimal formulation, significantly improving the intestinal release of phenolics and flavonoids (higher than TCC, which peaked in the gastric phase). **Conclusion:** Overall, CNF10 achieved the best balance of physicochemical, nutritional, bioactive, and sensory qualities, supporting its potential for developing functionally enhanced cookies. These findings highlight the potential of CNF as a functional ingredient for developing nutritionally enhanced and health-promoting cashew-based cookie products, with improved antioxidant capacity, potential reduction of oxidative stress, and supportive effects on cardiovascular health and lipid metabolism.

Keywords: antioxidants; bioactive compounds; cashew nut; cookie; *in vitro*simulated digestion

1. Introduction

Cashew nut (*Anacardium occidentale* L.) is a nutrient-rich nut, with the kernel characterized by a high content of lipids, protein, and dietary fiber [1,2]. It also provides sugars, B vitamins, calcium, magnesium, phosphorus, and potassium [2]. Owing to its nutritional value, desirable flavor, and associated health benefits, the global cashew industry has expanded considerably in recent years [3]. In addition to the kernel, cashew nut testa and shells are rich in bioactive compounds, including carotenoids zeaxanthin, γ-tocopherol, fatty acids (e.g., stearic, oleic, and linoleic acid), and phenolic compounds such as catechin, epicatechin, epigallocatechin, flavonoids, and other polyphenols [4,5]. These compounds are beneficial to health and show significant potential for applications in food technology. Polyphenols, particularly flavonoids, constitute a class of secondary metabolites that have attracted increasing attention in recent years due to their capacity to mitigate oxidative stress, cardiovascular diseases, cancer, and diabetes, while catechins also play an important role in health protection [4,5,6]. Numerous animal studies have demonstrated that dietary polyphenols, particularly flavonoids and tea catechins, can inhibit carcinogenesis in multiple organs, including the skin, lungs, esophagus, stomach, liver, small intestine, colon, bladder, prostate, and mammary glands [7,8]. Furthermore, cashew nut testa extract exhibits strong free radical scavenging activity, antibacterial activity against bacterial strains such as Escherichia coli and Staphylococcus aureus, and cytotoxic activity against liver cancer (HepG2), breast cancer (MCF-7) [9,10].

In recent years, there has been increasing interest in fortifying food products with functional ingredients derived from cereals, seeds, plants, and agro-industrial by-products to enhance nutritional quality and health benefits. Within this context, cookies represent a suitable food matrix for incorporating such ingredients. Previous stud-

ies have explored partial substitution of wheat flour with various natural sources, including cereals [11], green tea, millet [12], flaxseed [13], vegetables and fruits, or agricultural by-products [14,15]. These approaches improve nutritional profiles by increasing protein, dietary fiber, and mineral contents, while also enriching products with bioactive compounds such as polyphenols, flavonoids, and unsaturated fatty acids. Despite these advances, the utilization of cashew-derived materials, particularly those retaining the testa, remains limited. Most existing studies have focused on polished cashew kernels without testa for developing value-added products, such as ultrasound-assisted cashew milk [16], fermented cashew-based beverages using kefir and kombucha cultures [17], as well as cookie production [1]. Consequently, the potential of cashew kernels with intact testa combining both nutritional and bioactive components has not been fully explored in food applications. Furthermore, limited information is available regarding the behavior and release of these bioactive compounds during digestion when incorporated into complex food matrices.

Therefore, this study aimed to evaluate the effects of incorporating roasted cashew kernels with intact testa into cookies on their physicochemical properties, nutritional compositions, and the release of bioactive compounds under simulated *in vitro* gastrointestinal digestion conditions.

2. Materials and Methods

2.1 Materials

The cashew nuts with testa intact originated from Dong Nai Province, Vietnam and supplied by the Golden Cashew Company, wheat flour was purchased from the Interflour Vietnam, and other ingredients such as butter, sugar, eggs, and salt were purchased from a local supermarket. The chemicals and analytical reagents used in the study were obtained from the Sigma-Aldrich Company (St. Louis, MO, USA) and Merck (Merck, Darmstadt, Germany).

2.2 Preparation of Whole Cashew Nut Powder and Wheat Flour Blends

Whole cashew nuts with the testa intact were washed, drained, and roasted at 130 °C for 20 min using a rotary drum roaster to achieve a moisture content of less than 5%. After roasting, the nuts were finely ground to a particle size of less than 1 mm using a specialized nut grinder. The whole cashew nut powder was used to substitute wheat flour (WF) at levels of 5%, 10%, 15%, and 20% (w/w), and coded as CNF5, CNF10, CNF15, and CNF20, respectively. Cookies made from 100% wheat flour were used as the control sample.

2.3 Cookie Making

The cookies were formulated according to the methods of Aravind (2025) [15] with minor modifications. The dry ingredients consisted of wheat flour (250 g), salt (2 g), baking powder (3 g), and cashew nut powder added at different ratios as described above. To distinguish cookie samples from composite flours, the baked cookies were coded using a different system. Specifically, cookies prepared from WF, CNF5, CNF10, CNF15, and CNF20 were coded as WFC, C-CNF5, C-CNF10, C-CNF15, and C-CNF20. The mixture was thoroughly blended and sieved twice to ensure homogeneity. The mixing process was carefully controlled to avoid overmixing and thereby limit gluten formation. Butter (150 g) and granulated sugar (150 g) were manually creamed for 10 min to obtain a light and fluffy mass. Subsequently, vanilla flavoring solution (3 mL) was added and mixed for an additional 5 min. Finally, the dry ingredient was gradually incorporated into the creamed mass and mixed for 2 min. When a uniform and suitable dough structure was achieved, the dough was sheeted to a thickness of 0.8 cm and cut using a circular mold with a diameter of 5 cm. The cookie samples were placed on baking trays and baked at 160 °C for 20 min in an electric oven (Berjaya, BJY-E20KW-2BD, 2 Decks, Kuala Lumpur, Malaysia). After baking, the cookies were cooled to room temperature.

2.4 Physicochemical Properties of Blended Whole Cashew Nut Powder and Wheat Flour

The pasting properties of wheat flour and composite flours containing different levels of whole cashew nut powder substitution, including gelatinization temperature, peak viscosity, trough viscosity, final viscosity, breakdown, and setback, were determined according to the procedure described by Tien et al. [18]. Specifically, the wheat flour and cashew nut powder blends were prepared by mixing the flours with water at an appropriate ratio to obtain a suspension (15%, w/v), which was then heated from 30 °Cto 93 °C at 7.5 °C/min, holding for 15 min, cooled to 30 °C at the same rate, and finally maintained for an additional 15 min. The swelling index was determined by dispersing the flour mixture (1.0 g) in water (20 mL) and vortexing for 1 min. The mixture was incubated in a shaking water bath (200 ×g, 30 min, 93 °C), followed by cooling (tap water for 30 s and ice bath for 10 min) and centrifugation (4500 ×g, 10 min, 20 °C). The supernatant was removed, and the residue was weighed to calculate the swelling index. Water absorption capacity (WAC) was determined according to AACC Method No. 56-20 [19] with minor modification. Flour suspensions (1:20, w/v) were vortexed and centrifuged (3000 ×g, 15 min, 25 ± 2 °C). WAC was expressed as grams of water absorbed per gram of dry flour, while solubility was calculated as the percentage of dry matter lost after drying the residue at 50 °C for 24 h.

2.5 Texture Analysis

The hardness of cookies prepared from blended whole cashew nut powder and wheat flour was determined using a CT3 Texture Analyzer (Brookfield Engineering, Mas-

sachusetts, USA). Texture measurements were performed within 24 h after baking. A three point bending test was conducted using a three-point bend rig probe equipped with a 5 kg load cell and an automatic trigger. The test parameters were set as follows: a test distance of 5 mm, a pre-test speed of 2 mm/s, a test speed of 1 mm/s, and a post-test speed of 10 mm/s.

2.6 Proximate Composition of Cookies

The proximate composition of the cookies was analyzed according to AACC International Approved Methods [19]. Moisture content was determined using an infrared moisture analyzer (Method no. 44-01.01), ash content by incineration in a muffle furnace (Method no. 08-01.01), protein content by the Kjeldahl method (Method no. 46-10.01), and lipid content using a Soxhlet apparatus (Method no. 30-10.01). Carbohydrate content was calculated by difference as 100% minus the sum of the remaining components.

2.7 Bioactive Compounds Analysis

2.7.1 Sample Extraction

Bioactive compounds in cookie samples were extracted following the method described by Tomsone et al. [20] with a slight modification. Briefly, 2.5 g of each cookie sample was finely ground and extracted with 10 mL of an ethanol–water solution (80:20, v/v). The extraction was conducted at 25 ± 2 °C using an ultrasonic bath (Elmasonic S300H, Hohentwiel, Germany) operating at a frequency of 37 kHz for 30 min. Following extraction, the samples were centrifuged at 4500 ×g for 10 min at 4 °C using a Z326K centrifuge (Hermle Labortechnik, Wehingen, Germany). The supernatant was carefully collected, while the remaining residue was subjected to a second extraction under identical ultrasonic conditions for an additional 10 min. All supernatants obtained from both extraction steps were combined in a 25 mL volumetric flask and adjusted to volume with the extraction solvent. All extracts were prepared in triplicate and filtered through a 0.45 µm membrane filter prior to subsequent analysis of bioactive compounds.

2.7.2 Quantitative Analysis of Bioactive Compounds

The total phenolic content (TPC) of each sample was determined using the Folin–Ciocalteu reagent according to the method previously reported by Thanh et al. [9]. The absorbance of the reaction mixture was measured against a blank at a wavelength of 725 nm. The results were expressed as milligrams of gallic acid equivalents per gram of extract (mg GAE/g), calculated on a dry weight (DW) basis, using a calibration curve.

The total flavonoid content (TFC) of each sample was determined using a colorimetric method [9]. The absorbance of the reaction mixture was measured against a blank at a wavelength of 415 nm. The results were expressed as milligrams of rutin equivalents per gram of extract (mg RE/g), calculated on a dry weight (DW) basis, using a calibration curve.

The total catechin content (TCC) of each sample was determined using the vanillin assay [9]. The absorbance of the reaction mixture was measured against a blank at a wavelength of 500 nm. The results were expressed as milligrams of catechin equivalents per gram of extract (mg CE/g), calculated on a dry weight (DW) basis, using a calibration curve.

The antioxidant activities of the samples were determined using the DPPH radical scavenging [9]. After incubation, the absorbance of the reaction mixture was immediately measured at 515 nm using a spectrophotometer.

2.8 In-Vitro Gastrointestinal Digestion

The release of bioactive compounds was evaluated under *in vitro* conditions simulating the gastric and intestinal digestion stages according to the method of Rutz et al. [21] with minor modifications. The cookie powder (10 g) was transferred into a 50 mL centrifuge tube, followed by the addition of 30 mL of simulated gastric fluid and incubation at 37 °C. The simulated gastric fluid was prepared by dissolving NaCl (2 g/L) and pepsin (300 U/mL) in solution, and the pH was adjusted to 2.0 using concentrated HCl solution. The solution was then incubated at 37 °C in a shaking water bath for 2 h at a speed of 50 rpm. At the end of the gastric digestion phase, the pH was adjusted to 7.0–7.5 using $NaHCO_3$ before the addition of pancreatin (0.8 g/L) and bile salts (25 mg/mL). The solution was incubated at 37 °C in a shaking water bath for 1, 2, 3, 4, and 6 h. At different time points, samples were withdrawn, rapidly cooled, and centrifuged at 3000 ×g for 10 min prior to analysis. The release profile of total phenolic compounds (TPC), total flavonoid compounds (TFC), and total catechin compounds (TCC) was monitored at different time points.

2.9 Sensory Evaluation

The cookie samples were subjected to sensory evaluation focusing on color, flavor, texture, and overall quality. The evaluation panel consisted of 15 male and female experts aged 22–45 years, most of whom had studied food technology and had undergone training in sensory evaluation. This panel size is considered adequate for preliminary sensory evaluation. Samples were coded with random numbers and presented in randomized order to minimize bias. All participants provided informed consent prior to the evaluation. Sensory attributes were scored on a 9-point hedonic scale (1 = extremely dislike, 5 = neither like nor dislike, and 9 = extremely like) [22].

2.10 Statistical Analysis

The experiments were performed using three independently prepared cookie batches for each formulation. All analytical measurements were then conducted on samples collected from these independent batches, and the results

Table 1. Pasting properties of composite flours from wheat and whole cashew nut flours.

Sample	Pasting temperature (°C)	Peak viscosity (BU)	Trough viscosity (BU)	Final viscosity (BU)	Breakdown (BU)	Setback (BU)
WF	60.5 ± 0.2[a]	804 ± 14[a]	502 ± 9[a]	1245 ± 3[a]	302 ± 11[a]	743 ± 7[a]
CNF5	60.6 ± 0.2[a]	720 ± 19[b]	459 ± 3[b]	1095 ± 6[b]	261 ± 17[b]	636 ± 4[b]
CNF10	60.9 ± 0.4[a]	613 ± 17[c]	416 ± 5[c]	1018 ± 5[c]	197 ± 21[c]	602 ± 4[c]
CNF15	60.8 ± 0.5[a]	532 ± 13[d]	369 ± 3[d]	903.7 ± 21[d]	163 ± 10[cd]	534 ± 24[d]
CNF20	61.8 ± 0.2[b]	476 ± 1[e]	350 ± 17[d]	820 ± 8[e]	126 ± 16[d]	470 ± 19[e]

[1]WF, wheat flour; CNF5, CNF10, CNF15, CNF20, composite flours substituted with 5%, 10%, 15%, and 20% of whole cashew nut flour, respectively.

[2]Data followed by the same superscript letters in the same column are not significantly different ($p < 0.05$).

are presented as mean ± standard deviation (n = 3). Differences among samples were analyzed using analysis of variance (ANOVA). Statistical analyses were carried out using SPSS Statistics version 22 (IBM, New York, United States), and differences were considered statistically significant at $p < 0.05$.

3. Results and Discussion

3.1 Pasting Properties of Composite Flours From Wheat and WholeCashew Nut Flours

The pasting properties of composite flours from wheat and whole cashew nut flours are presented in Table 1. The pasting temperature of CNF5, CNF10 and CNF15 samples did not differ significantly from that of the WF sample, whereas the CNF20 sample showed a slight increase in pasting temperature. The peak, trough, final, and setback viscosities of the composite flours exhibited a linear decrease with higher CNF substitution levels. These results were due to the difference in compositional characteristics of whole cashew nut flour and their interactions with wheat flour components, which strongly affected starch gelatinization and pasting properties of the composite flours. Whole cashew nut flour contained high amounts of proteins, lipids, and dietary fiber, which competed with starch for available water, reducing the amount of free water accessible for starch hydration. Furthermore, these non-starch components can act as physical barriers surrounding starch granules, reducing their ability to swell freely. Consequently, the peak and trough viscosities of the composite flours decreased [23]. During cooling, the interactions among starch, proteins, lipids, and fiber in the composite flour limited the reassociation of amylose and amylopectin chains into an ordered gel network. As a result, the final and setback viscosities decreased, reflecting a weaker gel structure and reduced gel stability [24]. In addition, lipids might interact with amylose to form amylose–lipid complexes, which required higher thermal energy for gelatinization, resulting in a higher pasting temperature [23]. The lower viscosity of the composite flour indicates restricted starch swelling and gelatinization, which allows the dough to remain more fluid in the early stages of baking. This can promote greater spread of cookies, contributing to a thinner, wider cookie with a desirable crisp texture [25].

3.2 Swelling Index, Solubility, and Water Absorption Capacity of Wheat Cashew Composite Flours

Table 2 shows the swelling index, solubility, and water absorption capacity of the composite flours prepared from wheat and whole cashew nut flours. No significant differences ($p > 0.05$) were observed in the swelling index among all samples. In contrast, wheat flour exhibited higher solubility than the composite flours, while CNF20 showed the lowest value. No significant differences in solubility were found among CNF5, CNF10, and CNF15. The most pronounced difference was observed in the water absorption capacity of the composite flours. Significant differences ($p < 0.05$) were observed in water absorption capacity. Wheat flour showed the lowest value (1.24 ± 0.06 g/g), whereas the composite flours exhibited higher values ranging from 1.39 ± 0.05 to 2.03 ± 0.05 g/g, with the highest value observed for CNF15. These findings indicate that the partial replacement of wheat flour with whole cashew nut flour significantly enhanced the water-holding capacity of the composite system. The observed increase in water absorption capacity can be attributed to the higher protein and dietary fiber contents in CNF, which possess greater water-binding capacity than starch. The enhanced water retention within the matrix may also restrict the leaching of soluble components into the aqueous phase, thereby contributing to the decreasing trend in solubility [26]. Overall, the higher affinity of protein and fiber rich components in CNF for water, compared with wheat starch, plays a key role in modifying the functional properties of the composite flours.

3.3 Physical Properties and Hardness of Cookies Made From Composite Flours

Physical properties and hardness of cookies made from composite flours are given in Table 3. The moisture content of the cookies gradually decreased as the level of whole cashew kernel flour (CNF) used to partially replace wheat flour increased. The lower the moisture content of a food product, the greater its ability to inhibit microbial growth when stored in appropriate packaging, thereby extending its shelf life [27]. The cookie diameter showed statistically significant differences ($p \leq 0.05$). Compared with the WFC sample, C-CNF5, C-CNF10, C-CNF15, and C-CNF20 exhibited a gradual increase in diameter, with the

Table 2. Physical properties of composite flours from wheat and whole cashew nut flours.

Sample	Swelling index (g/g)	Water absorption capacity (g/g)	Solubility %
WF	17.7 ± 0.4^{a}	1.24 ± 0.06^{c}	21.4 ± 4.2^{a}
CNF5	17.2 ± 0.5^{a}	1.39 ± 0.05^{bc}	14.9 ± 2.1^{ab}
CNF10	17.5 ± 0.9^{a}	1.83 ± 0.12^{ab}	15.4 ± 1.0^{ab}
CNF15	17.4 ± 0.7^{a}	2.03 ± 0.05^{a}	15.3 ± 2.2^{ab}
CNF20	17.7 ± 0.5^{a}	1.70 ± 0.55^{ab}	13.4 ± 3.2^{b}

[1]WF, wheat flour; CNF5, CNF10, CNF15, CNF20, composite flours substituted with 5%, 10%, 15%, and 20% of whole cashew nut flour, respectively.

[2]Data followed by the same superscript letters in the same column are not significantly different ($p < 0.05$).

Table 3. Physical properties and hardness of cookies made from composite flours.

Sample	Moisture (%)	Diameter (mm)	Thickness (mm)	Hardness (N)
WFC	3.23 ± 0.02^{a}	60.1 ± 0.2^{c}	10.4 ± 0.5^{a}	14.0 ± 1.1^{a}
C-CNF5	2.33 ± 0.01^{b}	64.3 ± 0.8^{b}	10.1 ± 0.1^{ab}	12.3 ± 1.4^{a}
C-CNF10	1.98 ± 0.02^{c}	64.6 ± 0.5^{b}	10.6 ± 0.1^{a}	9.2 ± 0.3^{b}
C-CNF15	1.92 ± 0.03^{d}	64.9 ± 0.9^{b}	10.4 ± 0.2^{a}	7.8 ± 0.5^{bc}
C-CNF20	1.65 ± 0.04^{e}	67.6 ± 1.5^{a}	9.8 ± 0.2^{b}	6.1 ± 1.0^{c}

[1]WFC: control cookies (100% wheat flour); C-CNF5–C-CNF20: cookies with 5–20% substitution of wheat flour by whole cashew nut flour.

[2]Data followed by the same superscript letters in the same column are not significantly different ($p < 0.05$).

greatest difference observed for C-CNF20. The increase in cookie diameter (spread) was found to be influenced by the type of substituting ingredients and processing temperature, whereas no statistically significant differences were observed in cookie thickness [28]. Similar trends have been reported in previous studies, where the incorporation of flaxseed into cookie formulations led to an increase in cookie diameter with increasing substitution levels, while changes in cookie thickness remained insignificant [13].

The results also showeCenter for Experiment and Practiced that the breaking force of the cookies gradually decreased with increasing levels of CNF. Compared with the WFC sample, C-CNF10, C-CNF15, and C-CNF20 required lower breaking force. This may be attributed to the higher water absorption capacity of cashew nut flour; ; The decreased hardness of cookies containing CNF may be associated with gluten dilution and the higher water absorption capacity of CNF, which weakened the cookie structure and promoted a softer texture. This result is consistent with previous studies in which the incorporation of flaxseed [13] or whole amaranth flour [29] into cookie formulations resulted in a progressive reduction in cookie hardness as the substitution level of these ingredients increased. The spread and diameter of cookies are influenced by gluten formation and the fat content in the cookie formulation [30,31].

3.4 Proximate Composition of Cookies Made From Composite Flours

Table 4 shows the proximate chemical composition of cookies supplemented with whole cashew nut kernel flour (CNF) with different substitution levels. The protein, lipids and ash contents of cookies made from the composite flours significantly increased with increasing amount of CNF. In contrast, the carbohydrate content also tended to decrease gradually as the level of whole cashew nut supplementation in the cookie formulation increased. These results are also consistent with cookie formulations supplemented with soy protein isolate and quinoa protein isolate reported by Canti et al. (2025) [32]. The protein, fat, and carbohydrate compositions likewise showed similar results when cocoa husk was incorporated into cookie formulations [14]. Higher protein from whole cashew nut flour may dilute the gluten network of wheat flour, which promotes the spread and tenderness of the cookies. The high lipid content may improve dough plasticity, spread, mouthfeel, and browning, while the ash content may contribute to darker color. Overall, these components can improve cookie quality when used at appropriate levels but require careful formulation to maintain structural integrity and handling properties.

3.5 Bioactivity of Cookies Made From Composite Flour

Table 5 shows that the total phenolic content (TPC), total catechin content (TCC), total flavonoid content (TFC), and free radical scavenging capacity (%DPPH scavenging) increased as CNF supplementation rose from 5% to 20%, compared with the control sample. Cookie supplemented with 5% CNF to 20% CNF showed increases in TPC from 6.07 ± 0.19 to 13.80 ± 0.40 (mg GAE/g dried cookie), TCC from 0.98 ± 0.02 to 1.51 ± 0.10 (mg CE/g dried cookie), TFC from 0.35 ± 0.01 to 0.60 ± 0.03 (mg RE/g dried

Table 4. Proximate composition of cookies made from composite flours.

Sample	Protein (%)	Lipid (%)	Ash (%)	Carbohydrate (%)
WFC	6.26 ± 0.22^{c}	20.9 ± 0.9^{d}	1.09 ± 0.17^{b}	72.0 ± 0.3^{a}
C-CNF5	6.53 ± 0.15^{c}	22.5 ± 1.3^{c}	1.25 ± 0.16^{b}	69.6 ± 1.4^{b}
C-CNF10	6.91 ± 0.18^{b}	24.2 ± 0.3^{b}	1.29 ± 0.04^{b}	67.6 ± 0.4^{c}
C-CNF15	7.66 ± 0.08^{a}	25.9 ± 0.7^{a}	1.31 ± 0.19^{b}	65.2 ± 0.9^{d}
C-CNF20	7.89 ± 0.26^{a}	27.1 ± 0.3^{a}	1.54 ± 0.06^{a}	63.5 ± 0.5^{e}

[1]WFC: control cookies (100% wheat flour); C-CNF5–C-CNF20: cookies with 5–20% substitution of wheat flour by whole cashew nut flour.

[2]Data followed by the same superscript letters in the same column are not significantly different ($p < 0.05$).

cookie), and %DPPH scavenging from 13.0 ± 1.01% to 27.50 ± 0.92%. Similar results were reported in studies on cookie formulations supplemented with sorghum and millet [22]. The increase in TPC, TFC, and TCC with higher substitution levels is primarily attributed to the greater contribution of native bioactive compounds from the added ingredients and the enhanced release of bound forms during baking. In addition, thermal processing promotes Maillard reactions and phenolic transformations, leading to the formation of melanoidins and other compounds with antioxidant activity. These Maillard-derived products may also react with analytical reagents, contributing to an apparent increase in measured values rather than a true rise in native phenolic content [15,33,34]. The increase in TPC content was also observed in cookie formulations with increased supplementation of cocoa husk powder [14], banana peel powder [15] to partially replace wheat flour, or in gluten-free cookie formulations, where increasing the proportion of alfalfa seed powder also led to a gradual increase in TPC and free radical scavenging activity [34]. TPC, TFC, and free radical scavenging activity increased compared with the control sample in improved cookie formulations supplemented with green tea and millet [12]. Plant-based raw materials often contain high levels of bioactive compounds such as polyphenols, flavonoids, and antioxidant activity, especially in seeds [12]. Polyphenols, particularly flavonoids, are considered among the most important natural food constituents and are widely distributed in the human diet due to their unique antioxidant and antimicrobial properties [35]. The use of whole cashew kernels retaining the testa to supplement cookie formulations contributes to enhanced bioactivity, antioxidant capacity, and nutritional value of the cookies. Furthermore, supplementing cookies with whole cashew kernels not only utilizes the existing bioactive compounds and nutritional value but also contributes to the reuse of cashew testa by-products, thereby enhancing product value and reducing environmental pollution. This is considered a potential raw material source for the extraction of bioactive compounds for applications in the food and pharmaceutical industries.

3.6 Sensory Evaluation of Cookies Made From Composite Flour

Sensory evaluation of cookies supplemented with whole cashew nut flour (CNF) is presented in Table 6. Incorporation at 0–20% CNF affected sensory attributes, with optimal improvements observed at C-CNF10, beyond which quality declined. Color scores differed significantly ($p < 0.05$), with the C-CNF10 achieving the highest score (7.87 ± 1.06), significantly exceeding the C-CNF5, C-CNF15, and C-CNF20, while the C-CNF20 scored lowest. The observed decrease in color quality at higher supplementation levels may be attributed to the presence of fiber and natural compounds in the testa of cashew nut flour, which can influence color development. In addition, intensified Maillard reactions and sugar caramelization during baking could further contribute to the darker color observed in samples with higher CNF levels [1,11,36]. Although the CNF substitution also enhanced aroma, the taste scores were not significantly with the control cookie ($p < 0.05$). The C-CNF10 sample scored 6.93 ± 1.58, indicating a higher preference than the control and other substitution levels, although the difference was not statistically significant ($p > 0.05$), whereas the C-CNF5 sample received the lowest score (6.20 ± 1.82). Reduced taste at C-CNF15 and C-CNF20 may be attributed to a stringency from tannins and phenolics [15,37]. Texture scores also differed ($p < 0.05$), with the C-CNF10 was the highest (7.67 ± 0.90), indicating improved structure. Higher supplementation levels reduced preference, likely due to altered texture, moisture, or off-flavors. Overall acceptability was significantly different ($p < 0.05$) among the cookies. The C-CNF10 was rated highest, significantly exceeding C-CNF5 and C-CNF20, while WFC and C-CNF15 were intermediate. These results demonstrate that 10% CNF supplementation provided the optimal balance of color, aroma, texture, and flavor, yielding the highest consumer acceptance.

3.7 Release of Bioactive Components From Cookies After In Vitro Simulated Digestion

Fig. 1 illustrates the impact of cookies with supplementation of CNF at levels from 5% to 20% on the release of bioactive compounds, including total phenolic content

Table 5. Concentration of bioactive compounds and antioxidant capacity of cookies made from composite flours.

Sample	TPC (mg GAE/g dried cookie)	TCC (mg CE/g dried cookie)	TFC (mg RE/g dried cookie)	DPPH scavenging (%)
WFC	4.63 ± 0.31^{e}	0.59 ± 0.06^{e}	0.23 ± 0.01^{d}	4.62 ± 0.99^{e}
C-CNF5	6.07 ± 0.19^{d}	0.98 ± 0.02^{d}	0.35 ± 0.01^{c}	13.02 ± 1.01^{d}
C-CNF10	8.59 ± 0.31^{c}	1.21 ± 0.01^{c}	0.46 ± 0.05^{b}	19.71 ± 1.11^{c}
C-CNF15	10.40 ± 0.50^{b}	1.35 ± 0.09^{b}	0.52 ± 0.07^{b}	23.50 ± 0.97^{b}
C-CNF20	13.80 ± 0.40^{a}	1.51 ± 0.10^{a}	0.60 ± 0.03^{a}	27.50 ± 0.92^{a}

[1]WFC: control cookies (100% wheat flour); C-CNF5–C-CNF20: cookies with 5–20% substitution of wheat flour by whole cashew nut flour.

[2]Data followed by the same superscript letters in the same column are not significantly different ($p < 0.05$).

Table 6. Sensory evaluation of cookies made from composite flours.

Sample	Color	Aroma	Taste	Texture	Overall acceptability
WFC	6.53 ± 1.41^{ab}	6.73 ± 1.44^{a}	7.33 ± 1.04^{a}	7.27 ± 1.03^{a}	7.13 ± 0.92^{ab}
C-CNF5	5.67 ± 1.40^{bc}	5.73 ± 1.28^{a}	6.20 ± 1.82^{a}	6.87 ± 0.99^{a}	6.67 ± 1.05^{b}
C-CNF10	7.87 ± 1.06^{a}	6.93 ± 1.58^{a}	7.46 ± 1.13^{a}	7.67 ± 0.90^{a}	7.87 ± 0.64^{a}
C-CNF15	5.40 ± 1.24^{bc}	5.86 ± 1.68^{a}	7.26 ± 1.03^{a}	6.93 ± 1.62^{a}	6.80 ± 1.01^{ab}
C-CNF20	4.73 ± 1.22^{c}	5.73 ± 1.71^{a}	6.26 ± 2.02^{a}	6.13 ± 1.46^{a}	6.20 ± 1.47^{b}

[1]WFC: control cookies (100% wheat flour); C-CNF5–C-CNF20: cookies with 5–20% substitution of wheat flour by whole cashew nut flour.

[2]Data followed by the same superscript letters in the same column are not significantly different ($p < 0.05$).

(TPC), total flavonoid content (TFC), and total catechin content (TCC) under *in vitro* conditions. The proportion of cashew nuts partially replacing wheat flour influenced both the content of these bioactive compounds in the cookies and their release during simulated digestion. The release of TPC, TFC, and TCC during in vitro digestion was influenced by both CNF level and digestion time, with no clear dose-dependent trend observed at higher CNF substitutions (15–20%). Cookies supplemented at approximately 10% CNF exhibited the highest or comparable values across all three indicators, suggesting that beyond a certain threshold, interactions between TPC, TFC, TCC and the protein, starch, and fiber matrix may reduce their extractability and quantification, particularly after baking. During *in vitro* digestion, TPC (Fig. 1a) showed a progressive increase over time, with the most pronounced increase observed in the simulated intestinal phase (4–6 h). Similarly, El-Messery et al. (2021) [38] reported higher polyphenol release in intestinal fluids compared to gastric fluids. Similar trends have been reported in chestnut-supplemented cookies [39], reflecting the degradation of the matrix structure by digestive enzymes in the stomach and intestine, which facilitates the release of phenolics previously bound or trapped within the starch protein network [39,40]. However, it should be noted that the *in vitro* digestion model reflects the bioaccessibility of phenolic compounds rather than their actual bioavailability, as physiological processes such as intestinal absorption and metabolism are not considered. The TFC release increased sharply during the early stage of digestion, peaking at 4 h, and then gradually declined with prolonged digestion (Fig. 1b). This pattern was also observed in chestnut cookie formulations [39], and may be related to the limited stability of flavonoids under simulated intestinal conditions, where alkaline pH and digestive enzymes can promote oxidation or structural transformation. The C-CNF10 sample exhibited higher release levels and greater relative stability of TFC, whereas samples with higher substitution levels (C-CNF15–C-CNF20) showed an earlier and more pronounced decline in TFC. Nevertheless, these results are limited to *in vitro* conditions and do not necessarily indicate the actual absorption efficiency or biological activity of flavonoids *in vivo*. Meanwhile, TCC showed the greatest fluctuations during simulated digestion (Fig. 1c). Catechin was rapidly released during the early stage, reaching a maximum at 2 h, followed by a slight decrease in later stages. This early release aligns with findings by Ahmad et al. (2019) [8], where catechin content significantly increased during the first 2 h of the gastric phase. The phenomenon is consistent with catechin's susceptibility to pH changes, oxygen exposure, and digestive enzyme activity, resulting in more pronounced release and degradation at the initial stage. For samples with higher substitution levels (C-CNF15–C-CNF20), TCC release was significantly lower than that of the C-CNF10 sample, likely due to stronger binding of catechin within the polysaccharide- and fiber-rich testa matrix, limiting its accessibility and release under digestive conditions. Further studies using *in vivo* models or intestinal cell systems are required to confirm the bioavailability and metabolic fate of catechin.

Overall, these results suggest that functional food design requires balancing the content of bioactive compounds with their release potential. Among the tested formulations,

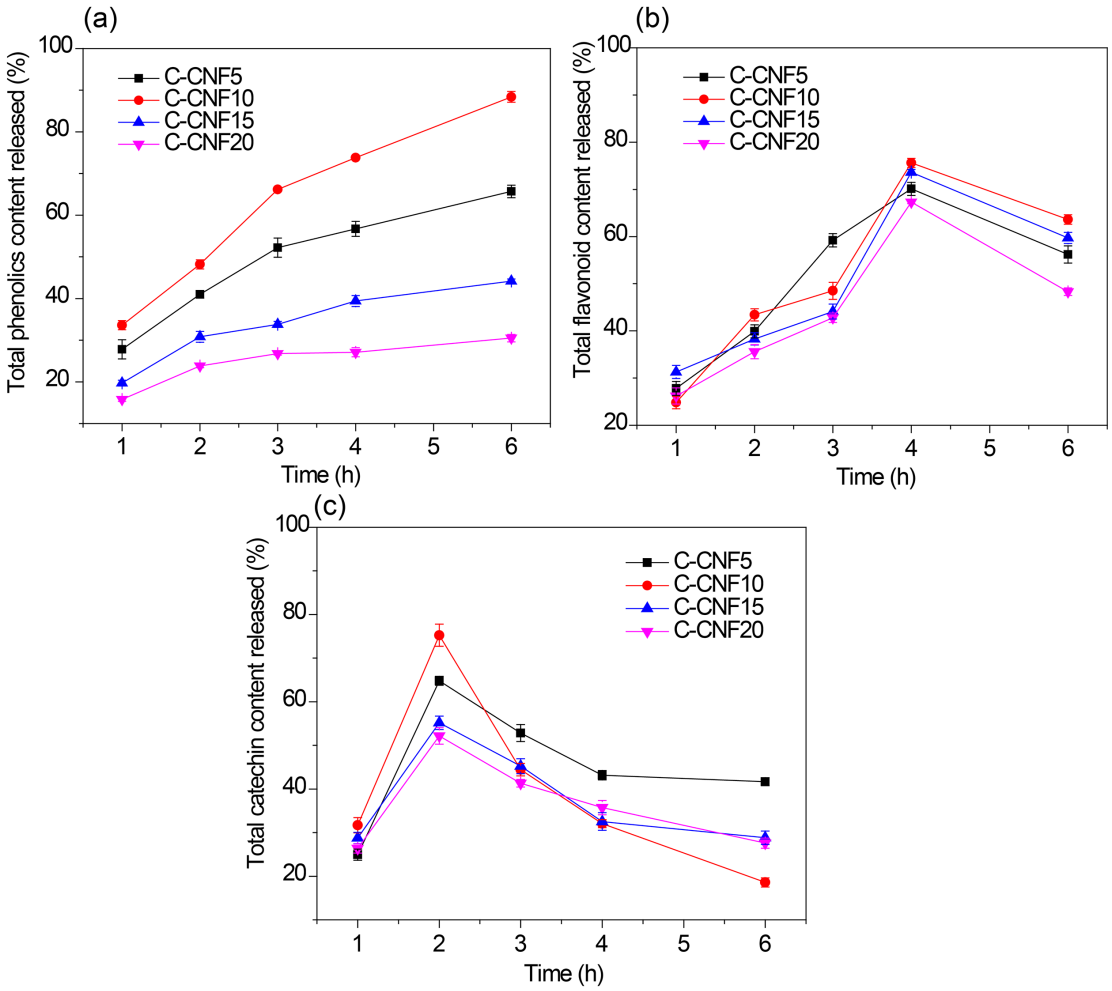

Fig. 1. Release of bioactive components from cookies after *in vitro* simulated digestion. (a) Total phenolics content released. (b) Total flavonoids content released. (c) Total catechin content released. C-CNF5–C-CNF20: cookies with 5–20% substitution of wheat flour by whole cashew nut flour.

the C-CNF10 sample showed the most favorable balance, providing both high initial content and favorable *in vitro* release of polyphenolic compounds. However, it should be noted that these findings are based on *in vitro* digestion and may not fully reflect *in vivo* bioavailability. These findings offer an important scientific basis for developing functional baked products with genuine nutritional and bioactive value, rather than merely increasing the content of bioactive-rich ingredients.

4. Conclusion

The study on the supplementation of cashew nuts with intact testa into cookie formulations demonstrates significant potential in enhancing nutritional value without substantially affecting the sensory quality of the product at appropriate supplementation levels. The presence of the testa contributes to increased contents of bioactive compounds such as phenolics, catechin, flavonoids, and antioxidant compounds, while simultaneously improving the functional properties of the product in a beneficial manner. These compounds can help reduce oxidative stress, thereby potentially lowering the risk of chronic diseases such as cardiovascular diseases and certain metabolic disorders. The results indicated that a supplementation level of 10% CNF maintained the structure, crispness, and characteristic flavor of the cookie, while delivering enhanced antioxidant capacity that may support cellular protection against free radical damage. Additionally, the study demonstrates the potential release of bioactive compounds under *in vitro* digestion conditions. Due to the availability of raw materials, low cost, and a technological process that does not require significant modifications, the application of cashew nuts with intact testa in cookie production is entirely feasible at an industrial scale. This research opens a pathway for the development of cookies enriched with bioactive compounds from agricultural by-products, contributing to the trend of functional and sustainable foods.

5. Limitations

While the findings suggest that CNF may enhance the nutritional and antioxidant properties of cashew-based cookies, the study's conclusions regarding reductions in oxidative stress and benefits to cardiovascular health and lipid metabolism are based on indirect indicators and do not establish clinical efficacy in humans. The bioavailability and stability of the bioactive compounds after digestion were not fully assessed, and the results may be influenced by the specific formulation, processing conditions, and storage parameters used in the study. Furthermore, sensory acceptance, long-term consumer compliance, and health outcomes require validation through *in vivo* studies and controlled human clinical trials before definitive health claims can be made.

Availability of Data and Materials

Data are available from the author on request.

Author Contributions

HVT designed the research study, conducted the experiments, analyzed the data, and wrote the manuscript. LQN, TTN, and LTKN assisted in material preparation and experimental work. NXH substantially contributed to the conception, provided guidance and support for the experiments, and supervised the project (equal). PVH designed the research study, contributed to manuscript drafting, and supervised the project (equal). All authors have contributed to the editorial changes made to the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

The authors gratefully acknowledge Ho Chi Minh City University of Industry and Trade (HUIT), Ho Chi Minh City, Vietnam for providing the facilities, infrastructure, and technical support necessary to conduct this research. The authors also thank the Golden Cashew Company (Dong Nai, Vietnam) for providing whole cashew nuts. The authors thank the participants of this study and the laboratories that performed the analytical work.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflicts of interest. This study used cashew samples provided by the Golden Cashew Company (Dong Nai, Vietnam). The company had no role in study design, data collection, analysis, interpretation, or manuscript preparation. The authors declare no other conflicts of interest.

References

[1] Liao M, Zhao Y, Xu Y, Gong C, Jiao S. Effects of hot air-assisted radio frequency roasting on nutritional quality and aroma composition of cashew nut kernels. LWT. 2019; 116: 108551. https://doi.org/10.1016/j.lwt.2019.108551

[2] de Carvalho JM, de Figueiredo RW, de Sousa PHM, de Luna FMT, Maia GA. Cashew nut oil: effect of kernel grade and a microwave preheating extraction step on chemical composition, oxidative stability and bioactivity. International Journal of Food Science & Technology. 2018; 53: 930–937. https://doi.org/10.1111/ijfs.13665

[3] da Silva J, de Brito ES, Ferreira SRS. Biorefinery of Cashew By-Products: Recovery of Value-Added Compounds. Food and Bioprocess Technology. 2023; 16: 944–960. https://doi.org/10.1007/s11947-022-02916-y

[4] Sruthi P, Roopavathi C, Madhava Naidu M. Profiling of phenolics in cashew nut (Anacardium occidentale L.) testa and evaluation of their antioxidant and antimicrobial properties. Food Bioscience. 2023; 51: 102246. https://doi.org/10.1016/j.fbio.2022.102246

[5] Chen Z, Farag MA, Zhong Z, Zhang C, Yang Y, Wang S, et al. Multifaceted role of phyto-derived polyphenols in nanodrug delivery systems. Advanced Drug Delivery Reviews. 2021; 176: 113870. https://doi.org/10.1016/j.addr.2021.113870

[6] Shahwan M, Alhumaydhi F, Ashraf GM, Hasan PMZ, Shamsi A. Role of polyphenols in combating Type 2 Diabetes and insulin resistance. International Journal of Biological Macromolecules. 2022; 206: 567–579. https://doi.org/10.1016/j.ijbiomac.2022.03.004

[7] Lambert JD, Hong J, Yang GY, Liao J, Yang CS. Inhibition of carcinogenesis by polyphenols: evidence from laboratory investigations. The American Journal of Clinical Nutrition. 2005; 81: 284S–291S. https://doi.org/10.1093/ajcn/81.1.284S

[8] Yang CS, Wang X, Lu G, Picinich SC. Cancer prevention by tea: animal studies, molecular mechanisms and human relevance. Nature Reviews Cancer. 2009; 9: 429–439. https://doi.org/10.1038/nrc2641

[9] Van Thanh H, Phi NTL, Khoi NT, Hoan NX, Van Hung P. Green extraction and biological activity of phenolic extracts from cashew nut testa using a combination of enzyme and ultrasound-assisted treatments. Journal of the Science of Food and Agriculture. 2023; 103: 5626–5633. https://doi.org/10.1002/jsfa.12641

[10] Lee JJL, Cui X, Chai KF, Zhao G, Chen WN. Interfacial Assembly of a Cashew Nut (Anacardium occidentale) Testa Extract onto a Cellulose-Based Film from Sugarcane Bagasse to Produce an Active Packaging Film with pH-Triggered Release Mechanism. Food and Bioprocess Technology. 2020; 13: 501–510. https://doi.org/10.1007/s11947-020-02414-z

[11] Wu D, Xu T, Sun Y, Ge F, Wang Y, Cheng W, et al. Effects of replacing sucrose and blending extrusion modified flours on the eating quality of highland barley sugar-crisp cookies. Food Research International (Ottawa, Ont.). 2025; 217: 116818. https://doi.org/10.1016/j.foodres.2025.116818

[12] Dhami K, Thapa P, Kumar S, Semwal P, Rai N, Anand J. Green tea-millets based multi-nutritive cookies: innovative formulation and nutritional analyses. Food Chemistry: X. 2025; 29: 102851. https://doi.org/10.1016/j.fochx.2025.102851

[13] Kaur P, Sharma p, Kumar V, Panghal A, Kaur J, Gat Y. Effect of addition of flaxseed flour on phytochemical, physicochemical, nutritional, and textural properties of cookies. Journal of the Saudi Society of Agricultural Sciences. 2019; 18: 372–377. https://doi.org/10.1016/j.jssas.2017.12.004

[14] Soares ID, Junqueira IG, Cirilo MEM, Vanin FM, Rodrigues CEDC. Defatted cocoa bean shells as an alternative flour for cookie production within a circular economy approach. Food Research International (Ottawa, Ont.). 2025; 221: 117543. https://doi.org/10.1016/j.foodres.2025.117543

[15] Aravind SM, Mattshe R, Prasanna P, Saran SP, Dharanesh D, Kumar SR, et al. Valorization and characterization of red banana (Musa acuminata) peel powder for the development of functional cookies. Food and Humanity. 2025; 5: 100683. https://doi.org/10.1016/j.foohum.2025.100683

[16] Cristina da Silveira Maia I, Cordeiro Macedo EB, Pereira dos Santos L, de Oliveira Bordin E, de Oliveira Lima L, Feihrmann AC, et al. Ultrasound as an alternative for pasteurization of cashew nut milks: Improvements in the rheological and technological properties, fatty acid profile and acceptance. Food Bioscience. 2025; 63: 105649. https://doi.org/10.1016/j.fbio.2024.105649

[17] Araujo Filho AAL, Sousa PHMD, Vieira IGP, Fernandes VB, Cunha FET, Magalhaes FEA, et al. Kombucha and kefir fermentation dynamics on cashew nut beverage (Anacardium occidentale L.). International Journal of Gastronomy and Food Science. 2023; 33: 100778. https://doi.org/10.1016/j.ijgfs.2023.100778

[18] Tien NNT, Duy NVK, Nhan LH, Phi NTL, Anh MNT, Thuan CM, et al. Starch digestibility and quality of gluten-free cookies made from unpolished red rice: effects of combined germination and heat-moisture treatment. Journal of Food Measurement and Characterization. 2025; 19: 6559–6567. https://doi.org/10.1007/s11694-025-03420-5

[19] International A. Approved Methods of the AACCI. 9th edn. AACC International: St. Paul, MN, USA. 2000.

[20] Tomsone L, Galoburda R, Kruma Z, Majore K. Physicochemical Properties of Biscuits Enriched with Horseradish (Armoracia rusticana L.) Products and Bioaccessibility of Phenolics after Simulated Human Digestion. Polish Journal of Food and Nutrition Sciences. 2020; 70: 419–429. https://doi.org/10.31883/pjfns/130256

[21] Rutz JK, Borges CD, Zambiazi RC, Crizel-Cardozo MM, Kuck LS, Noreña CPZ. Microencapsulation of palm oil by complex coacervation for application in food systems. Food Chemistry. 2017; 220: 59–66. https://doi.org/10.1016/j.foodchem.2016.09.194

[22] Aljobair MO. Physicochemical properties and sensory attributes of cookies prepared from sorghum and millet composite flour. Food Science & Nutrition. 2022; 10: 3415–3423. https://doi.org/10.1002/fsn3.2942

[23] Pycia K, Juszczak L. The Influence of the Addition of Nuts on the Thermal and Rheological Properties of Wheat Flour. Molecules (Basel, Switzerland). 2021; 26: 3969. https://doi.org/10.3390/molecules26133969

[24] Ribotta PD, Colombo A, León AE, Añón MC. Effects of Soy Protein on Physical and Rheological Properties of Wheat Starch. Starch - Stärke. 2007; 59: 614–623. https://doi.org/10.1002/star.200700650

[25] Devi A, Sindhu R, Khatkar BS. Morphological, pasting, and textural characterization of starches and their sub fractions of good and poor cookie making wheat varieties. Journal of Food Science and Technology. 2019; 56: 846–853. https://doi.org/10.1007/s13197-018-3544-9

[26] Akinwande F, Temitayo Olaleye H, Oresanya T. Quality attributes of cookies from wheat, lima bean and tigernut composite flour. Hrvatski Časopis Za Prehrambenu Tehnologiju, Biotehnologiju i Nutricionizam. 2023; 18: 22–28. https://doi.org/10.31895/hcptbn.18.1-2.2

[27] Akanbi TO, Nazamid S, Adebowale AA, Farooq A, Olaoye AO. Breadfruit starch-wheat flour noodles: Preparation, proximate compositions and culinary properties. International Food Research Journal. 2011; 18: 1283–1287.

[28] Suriya M, Rajput R, Reddy CK, Haripriya S, Bashir M. Functional and physicochemical characteristics of cookies prepared from *Amorphophallus paeoniifolius* flour. Journal of Food Science and Technology. 2017; 54: 2156–2165. https://doi.org/10.1007/s13197-017-2656-y

[29] Chauhan A, Saxena D, Singh S. Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. Cogent Food & Agriculture. 2016; 2. https://doi.org/10.1080/23311932.2015.1125773

[30] Jacob J, Leelavathi K. Effect of fat-type on cookie dough and cookie quality. Journal of Food Engineering. 2007; 79: 299–305. https://doi.org/10.1016/j.jfoodeng.2006.01.058

[31] Pareyt B, Talhaoui F, Kerckhofs G, Brijs K, Goesaert H, Wevers M, et al. The role of sugar and fat in sugar-snap cookies: Structural and textural properties. Journal of Food Engineering. 2009; 90: 400–408. https://doi.org/10.1016/j.jfoodeng.2008.07.010

[32] Canti M, Putra MF, Hutagalung RA, Hartanti AT, Della F. Physicochemical and sensory properties of novel cookies enriched with soy and anchovy protein isolate (Stolephorus insularis). Applied Food Research. 2025; 5: 100946. https://doi.org/10.1016/j.afres.2025.100946

[33] Saeed SMG, Ali SA, Faheem K, Ali R, Giuffrè AM. The Impact of Innovative Plant Sources (*Cordia myxa* L. Fruit (Assyrian Plum) and *Phoenix dactylifera* L. Biowaste (Date Pit)) on the Physicochemical, Microstructural, Nutritional, and Sensorial Properties of Gluten-Free Biscuits. Foods (Basel, Switzerland). 2022; 11: 2346. https://doi.org/10.3390/foods11152346

[34] Giuberti G, Rocchetti G, Sigolo S, Fortunati P, Lucini L, Gallo A. Exploitation of alfalfa seed (Medicago sativa L.) flour into gluten-free rice cookies: Nutritional, antioxidant and quality characteristics. Food Chemistry. 2018; 239: 679–687. https://doi.org/10.1016/j.foodchem.2017.07.004

[35] Delfanian M, Esmaeilzadeh Kenari R, Sahari MA. Utilization of Jujube Fruit (*Ziziphus mauritiana*Lam.) Extracts as Natural Antioxidants in Stability of Frying Oil. International Journal of Food Properties. 2015; 19: 789–801. https://doi.org/10.1080/10942912.2015.1043638

[36] Yuliana, Holinesti R, Tasrif N, Rahayu I, Hasanah AN, Helmizar, et al. Formulation, nutritional profile, and sensory acceptability of cookies incorporating locally sourced ingredients as complementary foods for toddlers: A strategy for stunting prevention. Food Chemistry Advances. 2025; 7: 101017. https://doi.org/10.1016/j.focha.2025.101017

[37] Oladunjoye AO, Justice IT, Apalara DR. Proximate, physical, microbiological and sensory evaluation of cookies from sorghum flour and hog plum (Spondias mombin L.) peels. Food and Humanity. 2025; 5: 100770. https://doi.org/10.1016/j.foohum.2025.100770

[38] El-Messery TM, Aly E, López-Nicolas R, Sánchez-Moya T, Ros G. Bioaccessibility and antioxidant activity of PCL-microencapsulated olive leaves polyphenols and its application in yogurt. Journal of Food Science. 2021; 86: 4303–4315. https://doi.org/10.1111/1750-3841.15893

[39] Pinto D, Moreira MM, Švarc-Gajić J, Vallverdú-Queralt A, Brezo-Borjan T, Delerue-Matos C, et al. In-vitro gastrointestinal digestion of functional cookies enriched with chestnut shells extract: Effects on phenolic composition, bioaccessibility, bioactivity, and α-amylase inhibition. *Food Bioscience*. 2023; 53: 102766. https://doi.org/10.1016/j.fbio.2023.102766

[40] Blanco Canalis MS, Baroni MV, León AE, Ribotta PD. Effect of peach puree incorportion on cookie quality and on simulated digestion of polyphenols and antioxidant properties. Food Chemistry. 2020; 333: 127464. https://doi.org/10.1016/j.foodchem.2020.127464