International Journal of Agriculture and Food Science 2026; 8(6): 362-367

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(6): 362-367
www.agriculturaljournals.com
Received: 06-04-2026
Accepted: 10-05-2026

Lailatul Azkiyah
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Ardiyan Dwi Masahid
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Yuli Witono
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Agustia Dwi Pamujiati
Department of Agribusiness, Universitas Kadiri, Kediri, Indonesia

Yesika Enno Prastiwi
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Sih Yuwanti
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Herlina
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Dinar Suksmayu Saputri
Research Center for Food Technology and Processing, National Research and Innovation Agency (BRIN), Jl. Jogja-Wonosari KM 31.5, Gunungkidul, Yogyakarta, Indonesia

Maria Belgis
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Lita Meilina
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Corresponding Author:
Lailatul Azkiyah
Department of Agriculture Product Technology, The University of Jember, Jember, Indonesia

Development of functional bread enriched with coffee husk flour: Physicochemical, fiber, and antioxidant characteristics

Lailatul Azkiyah, Ardiyan Dwi Masahid, Yuli Witono, Agustia Dwi Pamujiati, Yesika Enno Prastiwi, Sih Yuwanti, Herlina, Dinar Suksmayu Saputri, Maria Belgis and Lita Meilina

DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i6e.1618

Abstract
The increasing global production of coffee generates substantial amounts of agro-industrial by-products, including coffee husk (CH), which is rich in dietary fiber and antioxidant compounds. This study investigated the effects of partial substitution of wheat flour with CH flour on the physicochemical and functional properties of bread. Bread samples were prepared by substituting CH flour for wheat flour at levels of 0%, 1.5%, 3.0%, 4.5%, 6.0%, and 7.5% (w/w). The bread samples were analyzed for color, loaf expansion, texture, moisture content, ash content, dietary fiber, and antioxidant activity. The incorporation of CH flour significantly affected bread characteristics. Increasing levels of CH flour reduced the lightness (L*) value and loaf expansion while increasing bread hardness. Moisture and ash contents also increased due to the CH flour's high water-binding capacity and mineral content. Moreover, bread enriched with CH flour exhibited markedly higher total dietary fiber and antioxidant activity than the control bread. Total dietary fiber increased from 2.72% in the control bread to 9.47% in bread containing CH flour, while antioxidant activity increased from 6.09% to 26.53%. These findings demonstrate that CH flour has strong potential as a functional ingredient for improving the nutritional and functional properties of bread. The utilization of CH flour also represents a promising strategy for valorizing coffee-processing byproducts and developing sustainable functional bakery products with potential health benefits.

Keywords: Coffee husk flour, functional bread, dietary fiber, antioxidant activity, physicochemical properties

Introduction
Coffee is one of the most widely consumed beverages worldwide and is produced by brewing roasted coffee beans. According to the International Coffee Organization (ICO), global coffee production reached 177.51 million 60-kg bags in the 2024/2025 coffee year, representing a 5.2% increase compared to the previous year. South America remained the largest coffee-producing region, contributing 86.79 million bags, followed by Asia and Oceania with 49.64 million bags [1]. In addition, the United States Department of Agriculture (USDA) forecast that global coffee production would further increase to 178.68 million 60-kg bags in the 2025/2026 coffee year. Brazil remained the world's largest coffee producer with an estimated production of 65.0 million bags, followed by Vietnam (31.0 million bags), Colombia (12.5 million bags), and Indonesia (11.25 million bags), all of which contribute substantially to the global coffee industry [2]. With the continuous growth of the global population and consumer demand, coffee production and consumption are projected to increase further in the coming years.

The increasing production of coffee generates a considerable amount of agro-industrial by-products, as approximately 30-50% of the coffee fruit weight is discarded as waste. Coffee husk (CH) are among the major solid residues generated during the dry processing of coffee cherries, particularly after the dehulling stage. CH constitute approximately 12-18% of the dried coffee fruit weight. Due to the limited commercial utilization of CH, their disposal has become an environmental concern [3]. Therefore, numerous studies have focused on the valorization of coffee by-products to reduce environmental impacts while generating value-added products. CH have been investigated for several applications, including industrial materials such as ceramics, particle boards, and flavoring agents; biofuel production through solid fuel processing, gasification, and ethanol production; adsorption of contaminants; fermentation substrates for the production of organic acids and enzymes; extraction of bioactive compounds such as dietary fiber and antioxidants; and agricultural applications including animal feed, mushroom cultivation substrates, silage, and composting. In addition, CH are considered a promising raw material due to their high contents of fiber, carbohydrates, proteins, and phenolic compounds. Consequently, the development of coffee cherry tea, commonly known as cascara, has attracted increasing attention in recent years [4].

Chemically, CH are rich in carbohydrates (35-85%), soluble dietary fiber (30.8%), proteins (5-11%), and minerals (3-11%) [5]. Moreover, CH contain various phytochemical compounds, including tannins, anthocyanins, and polyphenols, which exhibit significant antioxidant activity and potential applications in food and pharmaceutical industries. The high dietary fiber and antioxidant contents of CH suggest their potential incorporation into food products to enhance nutritional and functional properties [3].

Bread is one of the most popular bakery products and serves as a major source of carbohydrates in many countries due to its convenience, affordability, and wide availability. Bread is typically produced from wheat flour fermented with baker's yeast (*Saccharomyces cerevisiae*), together with water, sugar, and other optional ingredients, followed by baking. The fermentation process produces a porous, sponge-like structure, characterized by gas cells within the bread matrix [6]. However, conventional bread is generally manufactured using refined wheat flour from which the bran and germ fractions have been removed. These fractions are important sources of dietary fiber, phytochemicals, vitamins, and minerals. Consequently, refined wheat bread usually contains relatively low levels of dietary fiber and antioxidant compounds (Xu *et al*., 2019).

To improve the nutritional and functional quality of bread, this study investigated the incorporation of CH flour into bread formulations. The addition of CH flour, which is rich in dietary fiber and antioxidant compounds, is expected to enhance the functional properties of bread and contribute to the development of fiber-enriched and antioxidant-rich bakery products with potential health benefits.

Materials and Methods

Coffee husk (CH) were obtained from a local coffee farmer in Jember District, Indonesia. Commercial wheat flour ("Cakra Kembar") was purchased from PT Indofood Sukses Makmur. Instant dry baker's yeast was obtained from Lesaffre. Sugar was supplied by Sugar Group Companies, while full cream milk powder was obtained from PT Indolakto. Hollman milk butter was purchased from Pilarose, and salt was obtained from PT UnichemCandi Indonesia. The chemicals used in this study included 1, 1-diphenyl-2-picrylhydrazyl (DPPH) purchased from Sigma-Aldrich, pancreatin enzyme, pepsin, and ethanol, all of analytical grade.

Preparation of Coffee Husk Flour

Dried coffee husk (CH) was soaked in boiling water (100°C) for 10 min, then rinsed with clean water. The CH were subsequently dried using a food dehydrator at 50°C for 12 h. The dried CH were then ground and sieved through an 80-mesh sieve to obtain coffee husk flour.

Bread Formulation

Wheat flour was partially substituted with CH flour at levels of 0%, 1.5%, 3.0%, 4.5%, 6.0%, and 7.5% (w/w). Bread prepared without CH flour served as the control. The bread formulation consisted of flour, yeast, salt, sugar, fat, and water. Baker's yeast was added in the form of a suspension. All ingredients were mixed with a mixer fitted with a dough hook attachment until a homogeneous dough formed. The dough was placed in a baking pan and subjected to the first fermentation (proofing) at room temperature for 30 min. Afterward, the dough was sheeted using a rolling pin to remove trapped gas and then molded into the desired shape. The molded dough underwent a second proofing at room temperature for 60 min in the baking pan. Subsequently, the dough was baked in an oven at 220°C for 20 min. After baking, the bread loaves were removed from the pans and cooled at room temperature prior to analysis.

Analytical Methods

Bread color was measured using a color reader (Minolta CR-10 Plus). The lightness value (L*) of the bread crust surface was determined 3 h after baking. Bread texture was evaluated using a Rheotex instrument (Sun Rheotex SD-700#). The expansion power of bread was determined according to the method described by Yuwono and Susanto (2001) [8]. Total dietary fiber content was analyzed according to the method of Asp (1984), which involves acid hydrolysis followed by enzymatic digestion. Antioxidant activity was determined using the DPPH (1, 1-diphenyl-2-picrylhydrazyl) radical scavenging assay. Moisture and ash contents were analyzed according to the methods described by the AOAC International (2005) [9].

Data Analysis

All experimental data were analyzed descriptively using IBM SPSS Statistics software. The results were presented as mean values obtained from experimental observations.

Results

Color Properties

The incorporation of coffee husk (CH) flour significantly affected the color characteristics of bread. The lightness (L*) value ranged from 32.57 to 45.12 in bread containing CH flour, whereas the control bread exhibited a significantly higher L* value of 62.50 (Fig. 1). The results indicate that the addition of CH flour produced darker bread compared with conventional wheat bread. Increasing the substitution level of CH flour progressively decreased the L* value, resulting in a darker appearance.

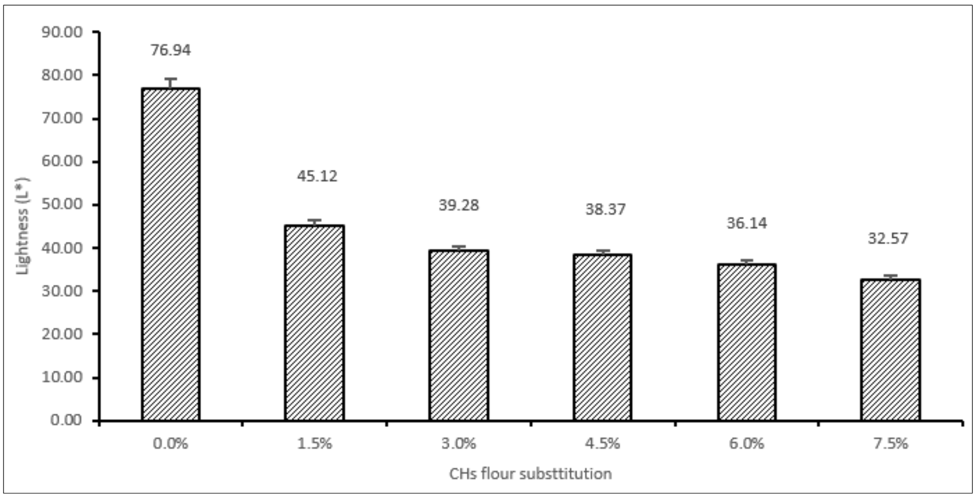

Fig 1: Lightness (L) value of bread formulated with different levels of coffee husk flour

Bread Expansion

Bread expansion ranged from 276.13% to 306.48% in bread containing CH flour, while the control treatment showed the highest expansion value of 309.17% (Fig. 2). The results demonstrated a gradual reduction in bread volume as the level of CH flour substitution increased.

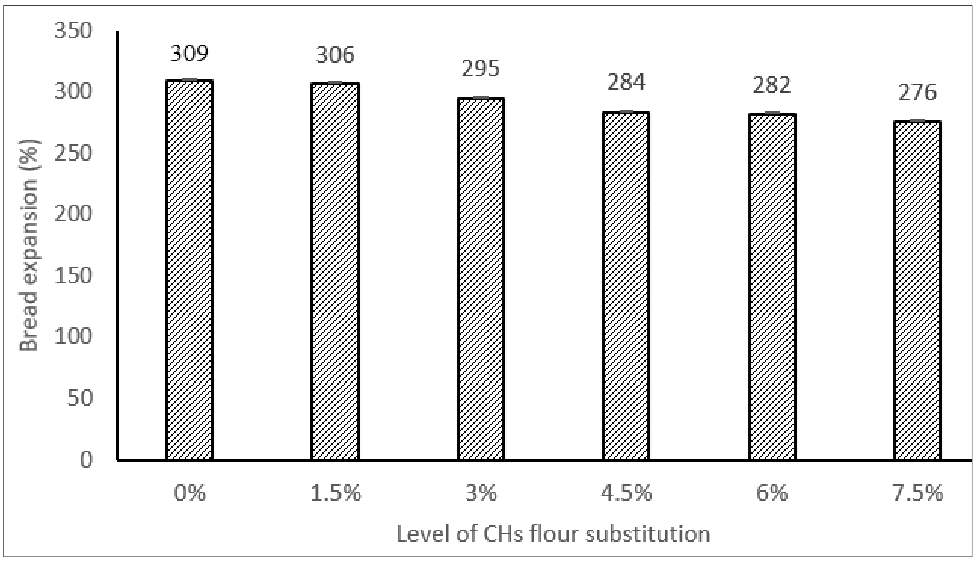

Fig 2: Bread expansion of bread formulated with different levels of coffee husk flour

Texture

The texture values of bread containing CH flour ranged from 4.31 to 6.24 g/mm, whereas the control bread showed a lower value of 3.98 g/mm (Fig. 3). Increasing the proportion of CH flour significantly increased bread hardness, resulting in a firmer and denser crumb structure.

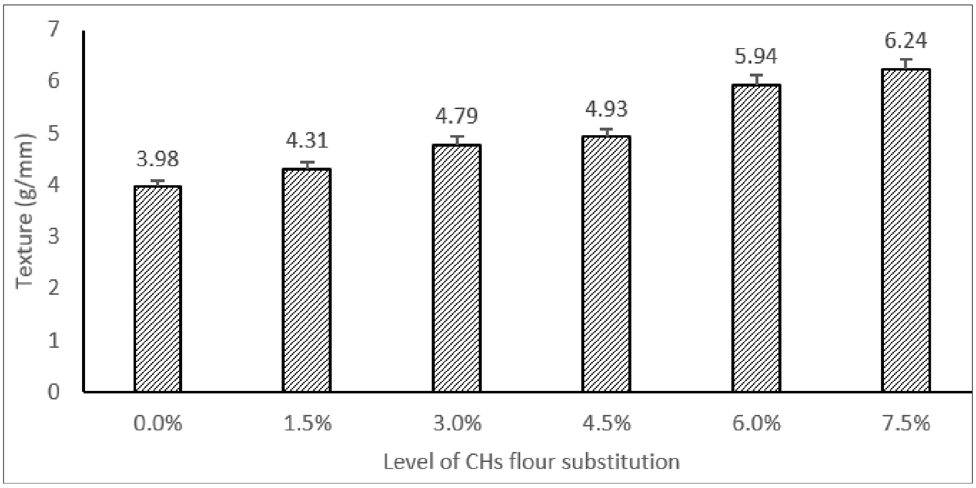

Fig 3: Texture values of bread formulated with different levels of coffee husk flour

Moisture Content

The moisture content of bread enriched with CH flour ranged from 37.57% to 39.50%, while the control bread contained 35.91% moisture (Fig. 4). The results indicate that CH flour increased the moisture retention capacity of bread. All formulations complied with the Indonesian National Standard (SNI) requirement for bread moisture content (<40%).

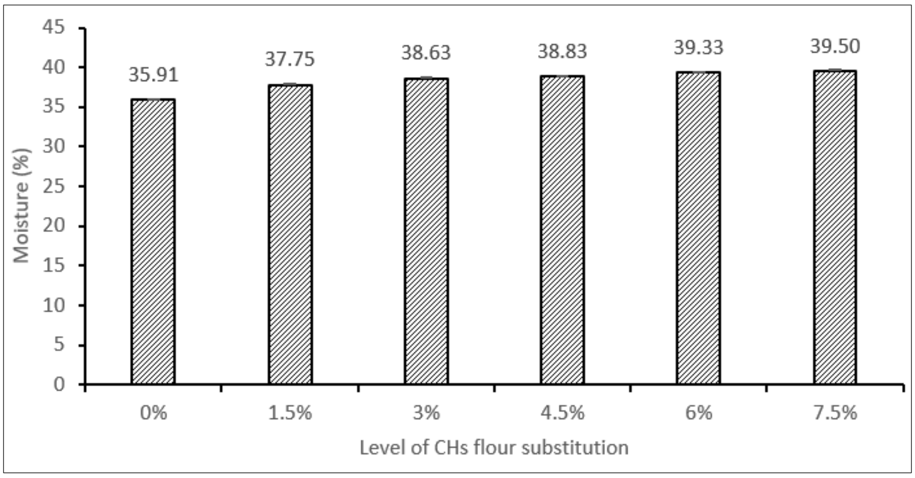

Fig 4: Moisture content of bread formulated with different levels of coffee husk flour

Ash Content

The ash content of bread containing CH flour ranged from 1.12% to 1.49%, whereas the control bread showed an ash content of 1.04% (Fig. 5). Increasing levels of CH flour significantly increased ash content, indicating a greater mineral contribution from the coffee husk flour.

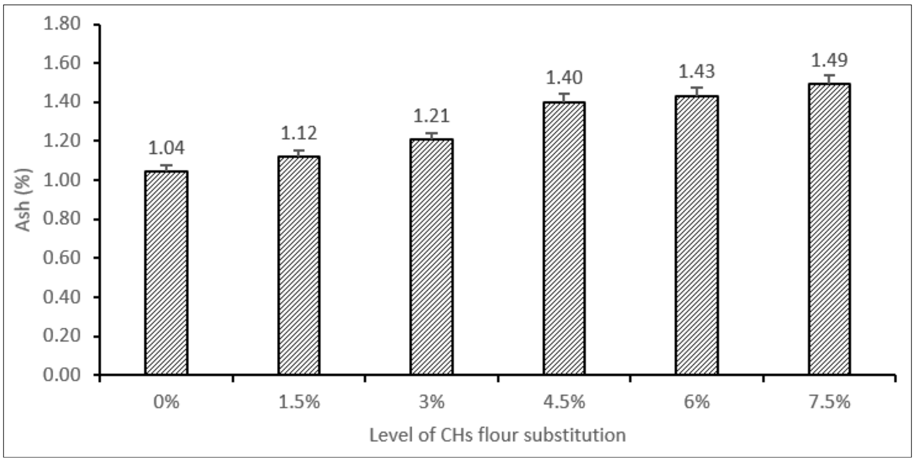

Fig 5: Ash content of bread formulated with different levels of coffee husk flour

Dietary Fiber Content

The total dietary fiber (TDF) content of bread enriched with CH flour ranged from 5.51% to 9.47%, consisting of insoluble dietary fiber (IDF) values of 4.79-7.78% and soluble dietary fiber (SDF) values of 0.72-1.69% (Fig. 6). In contrast, the control bread contained only 2.72% TDF. Dietary fiber content increased with increasing levels of CH flour, with IDF representing the predominant fraction.

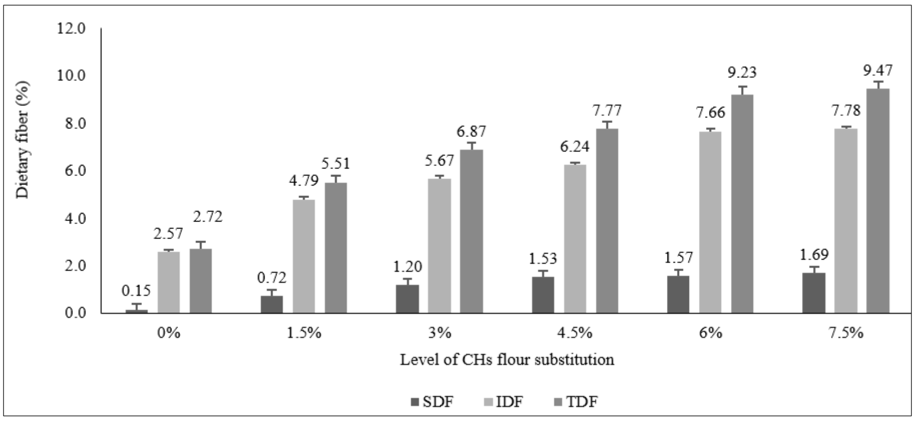

Fig 6: Dietary fiber content of bread formulated with different levels of coffee husk flour

Antioxidant Activity
The antioxidant activity of bread containing CH flour ranged from 12.11% to 26.53%, while the control bread exhibited an antioxidant activity of 6.09% (Fig. 7). Antioxidant activity increased significantly with increasing substitution levels of CH flour.

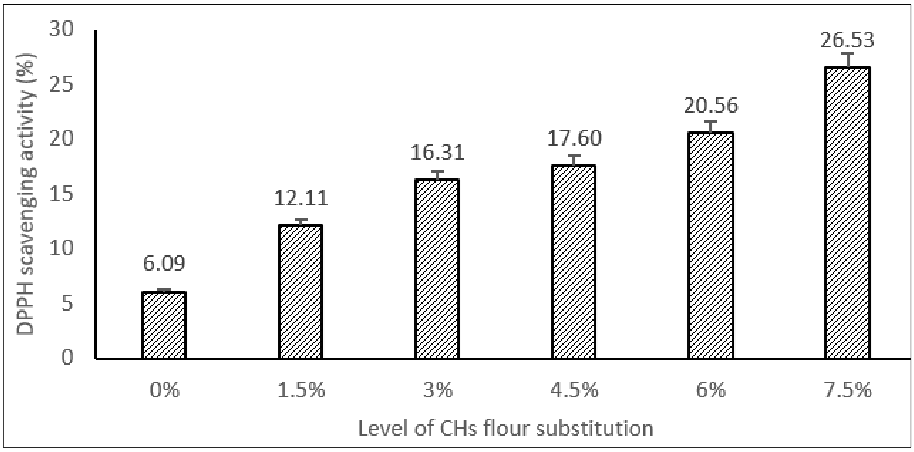

Fig 7: Antioxidant activity of bread formulated with different levels of coffee husk flour

Discussion
The decrease in bread lightness with increasing levels of CH flour can be attributed to the flour's dark brown color. Wheat flour generally exhibits a high L* value, whereas CH flour has a considerably lower L* value, resulting in darker bread as the substitution level increases. The brown color of CH flour is attributed to the oxidation of chlorogenic acid during drying, which forms brown compounds [10]. In addition, thermal processing during baking promotes Maillard reactions and caramelization, further intensifying the bread's brown coloration. Similar reductions in lightness have been reported in bakery products enriched with fiber-rich agricultural by-products. Although darker bread differs from conventional white bread, consumers often associate darker bakery products with higher nutritional value due to their fiber and antioxidant contents.

The reduction in bread expansion observed with increasing CH flour substitution is primarily related to the high dietary fiber content of CH flour. Dietary fiber interferes with the formation and continuity of the gluten network, thereby reducing the dough's ability to retain carbon dioxide produced during fermentation. Gluten proteins, mainly gliadin and glutenin, are responsible for forming an elastic structure that traps fermentation gases and promotes loaf volume expansion [11]. The incorporation of CH flour introduces non-gluten components that dilute and disrupt the gluten matrix. Furthermore, fiber particles may physically interfere with gas cell formation and stability, thereby reducing loaf volume. Similar findings have been reported for breads enriched with dietary fiber, where increased fiber incorporation generally decreases bread expansion and loaf volume [12, 13].

The increase in bread hardness following CH flour incorporation is closely associated with the reduction of gluten content and the high fiber concentration of CH flour. Since CH flour is gluten-free, replacing wheat flour with CH flour reduces the amount of gluten available to form a continuous, elastic dough network. Consequently, gas retention during fermentation is reduced, resulting in a denser crumb structure and firmer texture. In addition, dietary fiber particles disrupt the gluten matrix and enhance water absorption within the dough, promoting stronger interactions among starch, protein, and fiber components. These interactions contribute to the formation of a more compact structure and increased crumb firmness [11, 14]. Therefore, higher levels of CH flour produced bread with greater hardness and reduced softness compared to the control treatment.

The higher moisture content observed in bread containing CH flour is largely attributed to the water-holding capacity of dietary fiber. Fiber contains numerous hydrophilic groups capable of binding and retaining water molecules within the bread matrix. As a result, moisture loss during baking is reduced, leading to greater water retention in the final product. Previous studies have shown that fiber-rich materials possess strong water-binding properties and can significantly increase moisture retention in bakery products [15]. Moreover, interactions between dietary fiber, starch, and proteins may further limit moisture evaporation during thermal processing. Consequently, increasing the proportion of CH flour resulted in bread with higher moisture content than conventional bread.

The increase in ash content after substituting CH flour reflects the higher mineral content of coffee husk compared with wheat flour. Ash represents the inorganic residue remaining after complete combustion of organic matter and is commonly used as an indicator of total mineral content. Coffee husk contains substantial amounts of minerals, including potassium, calcium, magnesium, and phosphorus, which contribute to the higher ash content of the enriched bread. Therefore, increasing the proportion of CH flour proportionally increased mineral retention in the bread formulation. Similar increases in ash content have been reported in bakery products fortified with agricultural by-products rich in minerals and dietary fiber. The higher ash content observed in this study suggests that CH flour may enhance the mineral contribution of bread, thereby improving its nutritional value.

The substantial increase in dietary fiber content with CH flour incorporation can be directly attributed to the naturally high fiber content of coffee husk. Coffee husk contains large amounts of cellulose, hemicellulose, and lignin, which are classified as insoluble dietary fiber, as well as smaller amounts of soluble fiber components. Consequently, both total dietary fiber and its individual fractions increased as the level of CH flour substitution increased. The predominance of insoluble dietary fiber observed in this study is consistent with previous reports indicating that coffee husk is particularly rich in insoluble fiber fractions [16, 17]. The enhanced dietary fiber content may provide physiological benefits, including improved gastrointestinal function, increased satiety, and better metabolic health. Therefore, CH flour can serve as an effective functional ingredient for improving the nutritional profile of bread products.

The increase in antioxidant activity observed in bread containing CH flour is associated with the presence of bioactive compounds naturally occurring in coffee husk. Coffee husk contains various phenolic compounds, particularly chlorogenic acid and other polyphenols, which exhibit strong antioxidant properties. These compounds can donate electrons or hydrogen atoms to neutralize free radicals, thereby reducing oxidative reactions. As the proportion of CH flour increased, greater amounts of phenolic compounds were incorporated into the bread formulation, resulting in enhanced DPPH radical scavenging activity. Similar findings have been reported by Arpi *et al.* (2023) [18], who demonstrated the strong antioxidant potential of coffee husk. Therefore, incorporating CH flour not only increases the dietary fiber content but also improves the functional value of bread by enhancing antioxidant activity.

Conclusion

The incorporation of coffee husk (CH) flour into the bread formulation significantly influenced the bread's physicochemical and functional properties. Increasing levels of CH flour substitution produced darker bread with lower lightness values, reduced bread expansion, and firmer texture due to the disruption of gluten network formation by the high dietary fiber content of CH flour. In addition, CH flour increased the moisture and ash contents of bread due to its strong water-binding capacity and high mineral content. Most importantly, the addition of CH flour substantially enhanced the nutritional and functional quality of bread by increasing total dietary fiber and antioxidant activity. Bread containing CH flour met the criteria for high-fiber products and demonstrated improved antioxidant properties compared to conventional bread. Therefore, CH flour has strong potential as a functional food ingredient for developing fiber-enriched, antioxidant-rich bakery products while simultaneously supporting the sustainable valorization of coffee processing by-products.

Acknowledgments

We would like to express our gratitude to the Institute for Research and Community Service at the University of Jember for the Internal Reworking Scheme Grant provided for this research publication activity in 2025.

References

1. ICO. I-CIP retreats in April with improved global coffee outlook. London: International Coffee Organization; 2026.
2. USDA. Coffee: World Markets and Trade. Washington DC: United States Department of Agriculture; 2025.
3. Hoseini M, Cocco S, Casucci C, Cardelli V, Corti G. Coffee by-products derived resources. A review. Biomass Bioenergy. 2021;148:106009. https://doi.org/10.1016/j.biombioe.2021.106009
4. Thagunna B, Pokhrel B, Bachya Magar S, Lamichhane B, Kau J. Study on Coffee Cherry Its Chemical Characteristics, Processing and Its By-Product Utilization in Food: A Review. Malaysian Journal of Halal Research (MJHR). 2023;6(2):34-38. https://doi.org/10.26480/mjhr.02.2023.34.38
5. Muzaifa M, Rahmi F, Syarifudin. Utilization of Coffee By-Products as Profitable Foods-A Mini Review. IOP Conf Ser Earth Environ Sci. 2021;672(1):012077. https://doi.org/10.1088/1755-1315/672/1/012077
6. Rosell CM. The Science of Doughs and Bread Quality. In: Flour and Breads and their Fortification in Health and Disease Prevention. Amsterdam: Elsevier; 2011. p. 3-14. https://doi.org/10.1016/B978-0-12-380886-8.10001-7
7. Xu J, Wang W, Li Y. Dough properties, bread quality, and associated interactions with added phenolic compounds: A review. J Funct Foods. 2019;52:629-639. https://doi.org/10.1016/j.jff.2018.11.052
8. Yuwono S, Susanto T. Pengujian Fisik Pangan. Surabaya: Unesa University Press; 2001.
9. AOAC International. Official Methods of Analysis. 18th ed. Gaithersburg: AOAC International; 2005.
10. Ariva AN, Widyasanti A, Nurjanah S. Pengaruh Suhu Pengeringan Terhadap Mutu Teh Cascara dari Kulit Kopi Arabika (*Coffea arabica*). Jurnal Teknologi Dan Industri Pertanian Indonesia. 2020;12(1):21-28. https://doi.org/10.17969/jtipi.v12i1.15744
11. Rismaya R, Syamsir E, Nurtama B. Pengaruh penambahan tepung labu kuning terhadap serat pangan, karakteristik fisikokimia dan sensori muffin. Jurnal Teknologi dan Industri Pangan. 2018;29(1):58-68. https://doi.org/10.6066/jtip.2018.29.1.58
12. Chang RC, Li CY, Shiau SY. Physico-chemical and sensory properties of bread enriched with lemon pomace fiber. Czech Journal of Food Sciences. 2015;33(2):180-185. https://doi.org/10.17221/496/2014-CJFS
13. Pawiwara I, Triastuti D, Baharta R. Karakteristik roti tawar substitusi tepung bekatul dengan penambahan tepung daun kelor (*Moringa oleifera*). Jurnal Ilmiah Ilmu dan Teknologi Rekayasa. 2023;5(1):2023.
14. Rodriguez-Sandoval E, Polanía-Gaviria LY, Lorenzo G. Effect of Dried Cassava Bagasse on the Baking Properties of Composite Wheat Bread. J Texture Stud. 2017;48(1):76-84. https://doi.org/10.1111/jtxs.12212
15. Schleißinger M, Meyer AL, Afsar N, Nagy ÁG, Dieker V, Schmitt JJ. Impact of Dietary Fibers on Moisture and Crumb Firmness of Brown Bread. Advance Journal of Food Science and Technology. 2013;5(10):1281-1284.
16. Iriondo-Dehond A, Iriondo-Dehond M, Del Castillo MD. Applications of compounds from coffee processing by-products. Biomolecules. 2020;10(9):1-20. https://doi.org/10.3390/biom10091219
17. Rios MB, Iriondo-DeHond A, Iriondo-DeHond M, Herrera T, Velasco D, Gómez-Alonso S, *et al*. Effect of coffee cascara dietary fiber on the physicochemical, nutritional and sensory properties of a gluten-free bread formulation. Molecules. 2020;25(6):1358. https://doi.org/10.3390/molecules25061358
18. Arpi N, Muzaifa M, Andini R, Widayat HP, Nilda C, Nisa F. Physicochemical and sensory characteristics of cascara syrup with the addition of lemon (*Citrus limon*) extract. IOP Conf Ser Earth Environ Sci. 2023;1177(1):012028. https://doi.org/10.1088/1755-1315/1177/1/012028