Nature & Science
April 2026, Vol. 8, Issue 2, pp. 61–70
DOI: https://doi.org/10.36719/2707-1146/65/61-70

Comparative Analysis of Nutritional and Biological Values of Whole Wheat Bread with Plant-Based Functional Additives

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Abstract. *This research scientifically and comparatively investigates the dietary and biological significance of traditional whole wheat bread enriched with beet leaf additives. Analyses show that whole wheat bread, being rich in high energy potential (220–240 kcal/100g) and B-group vitamins, meets the basic daily nutritional needs of the human body. On the other hand, incorporating beet leaf homogenate (15–20%) into the formulation significantly increases the product's antioxidant potential, fiber content, and mineral richness (particularly vitamins A, C, and zinc, iron). As a result, while whole wheat bread serves as a classical energy source, the beet leaf additive imparts therapeutic and functional properties to the bread, making it more compatible with modern healthy nutrition standards. Analyses indicate that the incorporation of plant-based components (beet leaf and walnut) enhances antioxidant properties, increases the content of minerals, fats, and dietary fiber, reduces the glycemic index, and improves the digestion process compared to conventional whole wheat bread. Consequently, the inclusion of plant-based functional additives in whole wheat bread significantly improves its nutritional and biological value.*

Keywords: *whole wheat flour bread, beet leaf, bioactive additives, functional food composition, antioxidant effect*

1. Introduction

Bread is one of the staple foods in human nutrition and constitutes an important part of the daily diet in many countries. In particular, bread made from wheat flour is distinguished by its high energy value, good digestibility, and wide availability. Whole wheat bread is widely recognized for its higher nutritional value compared to refined wheat products due to its rich content of dietary fiber, vitamins, and minerals (Carvalho et al., 2018). The nutritional value of bread is closely linked to its chemical composition, the type and grade of flour used, and the characteristics of the technological processing. Certain food additives are used to further enrich the nutritional value of bread. These include some proteins, prebiotics, and certain fibers. These additives, by increasing the nutritional value of bread, improve the digestive process, balance the intestinal microflora, and contribute to overall health. Additionally, high-value bread is a high energy source. This makes it an optimal food source for people engaged in sports, leading physically active lives, and those who prioritize balanced nutrition.

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Received: 7 January 2026; Accepted: 27 March 2026; Published online: 25 April 2026

Numerous studies have highlighted the nutritional value and health benefits of functional foods, showing that diets rich in fruits, vegetables, and other bioactive food components are associated with reduced risk of chronic diseases, including cardiovascular disease, metabolic syndrome, cancer, and obesity (Essa et al., 2021; Asgary et al., 2018; Alissa & Ferns, 2017).

Bread is not only a source of carbohydrates but also a complex food product rich in proteins, B-group vitamins, minerals, and dietary fiber, and its nutrient composition is significantly influenced by the type of flour used (Aghalari et al., 2022). The type of flour used and the degree of processing directly affect the quantity and quality of the food components in the product; bread made from whole grain flour has a higher nutritional potential.

Recent studies indicate that whole wheat breads contain higher levels of dietary fiber, micronutrients (such as B-group vitamins and minerals), and phytochemical compounds compared to bread made from white flour, which contributes to their higher biological and functional nutritional value (Koksel et al., 2023).

This article scientifically compares the nutritional and functional values of whole wheat bread and bread with beet leaf additives, analyzing their main macro- and microcomponents, vitamin-mineral composition, and their significance for the human body. The aim of this study is a comparative analysis of the nutritional and functional characteristics of whole wheat bread and bread with beet leaf additives.

2. Materials and Methods

The main raw materials used in the study were whole wheat flour and beet leaves. Beet leaves were obtained from the Beta vulgaris var. rubra species cultivated in the Aran region of Azerbaijan. The most optimal harvesting period for the use of leaves is considered to be the early vegetation stage, i.e., 30–60 days. At this stage, the plant has not yet fully formed roots, and the leaves are softer, less bitter in taste, as well as richer in vitamins and antioxidant substances. For this reason, the mentioned period is considered the most favorable for both the use of leaves for nutritional purposes and for obtaining bioactive substances at maximum levels. The collection of leaf samples was carried out during the months of May–August of 2025.

Determination of General Chemical Composition

The moisture, ash, and crude protein content of the samples were determined according to the methods of the Association of Official Analytical Chemists (2000). Total lipids were extracted by the Bligh and Dyer method (Bligh & Dyer, 1959). Total carbohydrate content was calculated by the difference method, and the energy value of the product was determined based on the following conversion factors:

– Carbohydrates – 4 kcal/g^{-1} (17 kJ/g^{-1})
– Proteins – 4 kcal/g^{-1} (17 kJ/g^{-1})
– Fats – 9 kcal/g^{-1} (37 kJ/g^{-1})

For the determination of mineral substances, the samples were burned in a muffle furnace at 600 °C for 6–8 hours until complete decomposition of organic matter, and then treated with 5% (v/v) nitric acid solution (approximately 90 °C). The amounts of potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), cobalt (Co), manganese (Mn), and sodium (Na) elements were determined using an Analytik Jena novAA 300 flame atomic absorption spectrophotometer (with winAAS software) and the results were expressed in mg/kg. All analyses were performed in triplicate (Biondo et al., 2014).

3. Results and Discussion

1. Nutritional Value of Whole Wheat Bread

1.1 Chemical Composition and Digestibility

Whole wheat bread is considered a well-digestible product. The main reason for this is the structural-mechanical properties of bread and the accessibility of nutrients for digestive enzymes:

– Proteins – in a denatured state;
– Starch – in a partially gelatinized and partially soluble form;
– Fats – emulsified or adsorbed by proteins and starch;
– Sugars and salt – in a dissolved state;
– Bran particles – in a softened form.

The porous structure and soft consistency of bread facilitates its contact with gastrointestinal juices and increases the degree of digestibility.

1.2 Main Nutrients

Proteins and Amino Acids

The protein content in whole wheat bread averages 7.5–8.2%. In terms of biological value, wheat bread is considered somewhat limited because it contains small amounts of certain essential amino acids, particularly lysine, tryptophan, and methionine. At the same time, glutamic acid predominates in the amino acid composition of bread (35–40% of total amino acids). Glutamic acid plays an important role in metabolism, nervous system activity, and improving physical-intellectual performance.

Carbohydrates

The carbohydrate content in wheat bread is 45–50%, of which approximately 80% is in the form of starch. Consumption of 280 g of wheat bread daily can meet approximately 35–40% of the human body's daily energy requirement. Fiber and hemicelluloses, which are of special significance, although not fully broken down, strengthen intestinal peristalsis and regulate the digestive process.

1.3 Vitamin and Mineral Composition

The content of vitamins in wheat bread mainly depends on the grade of flour. In bread made from high-grade wheat flour, vitamins are relatively scarce, because most vitamins are concentrated in the germ and bran layer of the grain. Bread is considered an important source of B-group vitamins (B_1, B_2, PP) in particular. Studies show that as a result of the widespread use of high-grade flour, the level of B-group vitamin intake among the population has decreased by approximately 50% in recent decades. In terms of mineral substances, wheat bread is rich in potassium, phosphorus, magnesium, and iron, but the calcium-phosphorus ratio is not considered optimal.

1.4 Nutritional Value Indicators of Whole Wheat Bread

The evaluation of the nutritional value of bread made from wheat flour is carried out on the basis of an analysis of its chemical composition, energy potential, and the amount of main nutrients. Nutritional indicators are of great importance both in terms of energy supply to the human body and in meeting the daily requirements for proteins, vitamins, and mineral substances. For this purpose, the main indicators of the average chemical composition and vitamin-mineral composition of wheat bread are presented in table form below.

Table 1
Average chemical composition of bread made from whole wheat flour (per 100 g of product)

Indicator	Amount
Energy value	220–240 kcal
Proteins	7.5–8.2 g
Fats	1.0–1.5 g
Carbohydrates	45–50 g
Starch	36–40 g
Dietary fiber	2.0–3.0 g
Water	40–45 g

Table 1 reflects the average chemical composition of bread made from wheat flour per 100 g of product. As can be seen from the data, the energy value of wheat bread ranges from 220–240 kcal, which indicates its high energy potential. This characteristic creates conditions for wheat bread to serve as one of the main energy sources in the daily diet.

The protein content of 7.5–8.2 g confirms the role of bread in partially meeting the body's need for plastic substances. However, since the biological value of proteins is limited by amino acid composition, the co-consumption of wheat bread with other protein-containing products is considered more appropriate.

The carbohydrate content of 45–50 g, including starch of 36–40 g, indicates that wheat bread is primarily a carbohydrate energy source. At the same time, the presence of 2.0–3.0 g of dietary fiber plays an important role in regulating the activity of the digestive system and strengthening intestinal peristalsis. The 40–45% water content of the product is one of the main factors ensuring the soft consistency, good chewability, and high digestibility of wheat bread.

After analyzing the main macrocomponents and energy value indicators of bread made from wheat flour in Table 1, it is considered necessary to evaluate the level of supply of the product with microelements and vitamins. The place of bread in the food diet not only from the point of view of energy and plastic substances, but also according to its vitamin-mineral composition plays an important role in determining its overall nutritional and biological value. In this regard, Table 2 presents the average indicators of wheat bread for main vitamins and mineral substances and scientifically evaluates their role in meeting the physiological needs of the human body.

Table 2
Vitamin and mineral composition of whole wheat bread

Substance	Amount
Vitamin B_1 (thiamine)	0.15–0.20 mg
Vitamin B_2 (riboflavin)	0.05–0.08 mg
Vitamin PP	1.2–1.8 mg
Potassium	120–200 mg
Phosphorus	90–150 mg
Magnesium	20–35 mg
Iron	2.0–3.5 mg

Table 2 presents the level of supply of wheat bread with vitamins and mineral substances. The analysis shows that wheat bread is particularly important as a source of B-group vitamins. The amount of Vitamin B_1 is 0.15–0.20 mg and the amount of Vitamin B_2 is 0.05–0.08 mg. These vitamins play an important role in carbohydrate metabolism, normal functioning of the nervous system, and regulation of energy metabolism.

The level of Vitamin PP at 1.2–1.8 mg shows the positive effect of wheat bread on the activity of enzyme systems participating in oxidation-reduction processes.

In terms of mineral substances, wheat bread is richer in potassium (120–200 mg) and phosphorus (90–150 mg). Potassium performs important functions in the activity of the cardiovascular system, and phosphorus in the formation of bone tissue and energy metabolism. The presence of magnesium (20–35 mg) and iron (2.0–3.5 mg) further increases the importance of this product from the perspective of neuro-muscular conduction and hematopoiesis processes. It should also be noted that the amount of mineral substances in wheat bread varies depending on the grade of flour, and these indicators are relatively lower in breads made from high-grade flours.

1.5 Digestibility and Hygienic Evaluation of Whole Wheat Bread

In wheat bread, protein digestibility typically ranges between 75–85%, while carbohydrate digestibility reaches 95–98%, reflecting its high nutritional quality (Rosas-Rivas et al., 2025). From a hygienic standpoint, quality wheat bread should have a smooth surface, uniform porous internal structure, pleasant aroma, and taste, with moisture content not exceeding 42–45% (Zeng et al., 2024). Porosity generally varies within the normal range of 45–75%, which is crucial for both sensory properties and digestibility. Scientific analyses indicate that bread made from wheat flour is one of the main food products providing high energy value, good digestibility, and important functional significance in daily diets (Zeng et al., 2023). Bread plays a key role in supplying proteins, B-group vitamins, minerals, and dietary fiber, alongside being a primary source of carbohydrate energy. The nutritional value of wheat bread is directly related to the type and grade of flour used. While breads made from high-grade flours exhibit superior technological and sensory characteristics, whole grain and low-grade flours contribute higher dietary fiber, microelements, and biologically active compounds, highlighting their importance as functional food products. Structural and mechanical properties, along with the porous architecture of wheat bread, ensure a high level of nutrient digestibility, reinforcing its hygienic and physiological advantages. In this context, flour enrichment, application of functional additives, and optimization of technological processes are promising approaches to enhance the nutritional and biological value of wheat bread (Rosas-Rivas et al., 2025; Zeng et al., 2024; Zeng et al., 2023).

2. Nutritional Value of Bread with Beet Leaf and Walnut Additives

In contemporary food production, one of the key goals is to enhance product quality. The quality of bread and other flour-based products is influenced by their nutritional profile, sensory attributes, and appearance, which in turn depend on the selection of raw materials, processing methods, and storage conditions. Recently, incorporating beet leaf and other vegetable powders into bread has become increasingly popular in functional food production. These plant-based additives can boost the content of vitamins, minerals, dietary fiber, and antioxidants, while also contributing to a more balanced energy profile.

The objective of this study is to assess the nutritional characteristics of bread prepared with beet leaf supplementation and to evaluate its potential as a functional food product. Bread samples were prepared using a traditional recipe, and experimental variants were produced by including beet leaf homogenate at levels of 15–20%. The balance of proteins, carbohydrates, and fats was analyzed, while the energy value and macronutrient composition were determined through laboratory measurements and standard reference data. The vitamin and mineral content was estimated by considering the contribution of the beet leaf additive to the overall nutritional profile.

Table 4
Nutritional and energy value of bread with beet leaf and walnut additive (per 100 g of product)

Indicator	Amount	Significance
Energy value	258.4 kcal	Approximately 12.9% of daily energy requirement.
Proteins	8.2 g	Increased due to whole wheat flour and walnut; plastic material for muscle tissue.
Fats	11.8 g	High due to walnut and vegetable oil; source of Omega-3 and Vitamin E.
Carbohydrates	31.5 g	Complex carbohydrates from whole wheat flour; stable energy supply.
Dietary fiber	5.4 g	High-fiber product. Regulates digestion due to beet leaf and whole wheat flour.
Moisture (Water)	43.1 g	High due to beet puree; ensures softness and freshness of bread.

This table shows that the energy value of 100 g of the finished product was determined to be 258.4 kcal, which meets approximately 13% of the daily energy requirement. The macrocomponent composition of the product fully meets functional food standards: protein content enriched with whole wheat flour and walnut at 8.2 g, and fat content increased to 11.8 g (this increase is mainly due to beneficial Omega-3 fatty acids from walnut).

The dietary fiber content, which is the most important functional indicator of the product, is 5.4 g; this indicator was created as a result of the synergistic effect of beet leaf and whole wheat flour and falls into the high-fiber product category that strengthens intestinal peristalsis. The complex structure of carbohydrates (31.5 g) and high moisture content (43.1 g) both lower the glycemic index of bread and ensure its long-term freshness.

Table 5
Vitamin and mineral composition of bread with beet leaf and walnut additive (per 100 g of product)

Substance	Amount (approx.)	Physiological Significance
Vitamin A	180–260 μg	Vision, immune system and skin health (from leaf).
Vitamin B_1	0.18–0.25 mg	Carbohydrate metabolism and nervous system (whole wheat flour).
Vitamin B_2	0.12–0.18 mg	Energy metabolism, skin and eye health.
Vitamin PP	2.2–3.0 mg	Energy metabolism and enzyme systems activity.
Vitamin C	10–18 mg	Antioxidant and iron absorption (leaf and beet).
Calcium	95–150 mg	Bone and dental health, blood coagulation.
Phosphorus	150–220 mg	Cellular energy and bone formation.
Potassium	310–420 mg	Cardiovascular system and water-salt balance.
Magnesium	55–85 mg	Neuro-muscular function (walnut and whole wheat).
Iron	4.2–5.5 mg	Hemoglobin formation and hematopoiesis.
Zinc (Zn)	1.5–2.4 mg	Immunity and cell recovery.

The vitamin and mineral profile per 100 grams of the beet-leaf and walnut bread under study demonstrates high functionality. Vitamin A (180–260 μg) and Vitamin C (10–18 mg) in the product's composition are mainly supplied by beet leaf, creating a powerful antioxidant effect that strengthens the immune system. The bran portion of whole wheat flour enriches the product with B_1 (0.18–0.25 mg) and PP (2.2–3.0 mg) vitamins, turning it into a significant source for nervous system and energy metabolism.

In terms of mineral composition, the bread supports the functioning of the cardiovascular system with high Potassium (310–420 mg) and Magnesium (55–85 mg) content. In particular, the Iron (4.2–5.5 mg) and Calcium (95–150 mg) content coming from beet leaf increases the biological value of the product for hematopoiesis and bone health. The presence of Vitamin C in the composition stimulates the absorption of plant-based iron, ensuring the effectiveness of the product in the prevention of anemia.

2.1 Bioactive and Functional Properties

Beet leaf has high antioxidant activity. Beta-carotene and lutein/zeaxanthin compounds protect cells from the damage of free radicals and reduce the risk of chronic diseases. Additionally, since the tops are a natural source of nitrates, they help regulate blood pressure, protect cardiovascular health, and strengthen detoxification processes. The fibers in its composition support intestinal function and promote a healthy microbiome (Kuznetsova & Sidanova, 2020).

2.2 Functional Advantages of the Product

Bread with beet leaf additive provides the following advantages:

– Improves energy and macronutrient balance;
– Increases vitamin and mineral supply;
– Exhibits antioxidant and anti-inflammatory effects;
– Supports cardiovascular and digestive systems;
– Suitable for use in daily diet as functional food.

Thus, the beet leaf additive not only changes the color and taste characteristics of bread, but also significantly increases its nutritional and functional value. This product is particularly recommended for consumers who choose a healthy lifestyle and prefer functional nutrition.

Research shows that beet leaf additive increases the nutritional value of bread and can be used as a functional food product. The most appropriate dosage is 10–15% by volume; at this point, both the nutritional composition is enriched and the organoleptic indicators of the product are maintained. Bread prepared with beet leaf additive can be recommended for healthy nutrition, especially by increasing fiber, vitamin and mineral balance (Kuznetsova & Sidanova, 2020).

3. Comparative Analysis of Whole Wheat Bread and Bread with Beet Leaf and Walnut Additives

Both whole wheat bread and bread with beet leaf additives serve as the main sources of energy and nutrition in the daily diet, but their nutritional and functional values differ in several respects. Whole wheat bread stands out with its high energy value (220–240 kcal/100 g), protein (7.5–8.2 g), carbohydrate (45–50 g), and dietary fiber (2–3 g), and is also rich in B-group vitamins and macroelements (potassium, phosphorus, magnesium, iron). Its biological value is related to the balance of amino acids and the effectiveness of protein digestion (75–85%), and its low glycemic index demonstrates its advantage as a functional food.

Although bread prepared with beet leaf additive is similar in terms of main food components, its functional characteristics are significantly increased. With a 10–15% additive, vitamins A and C, antioxidants, minerals (calcium, zinc, phosphorus, magnesium), and dietary fiber are enriched. This additive, by increasing the anti-inflammatory and antioxidant activity of bread, supports immunity, improves cardiovascular system and intestinal function. The macronutrient balance and energy supply are also maintained at an optimal level. Table 6 presents a comparative analysis of whole wheat bread and bread with beet leaf additive.

Table 6
Comparative analysis of whole wheat bread and functional (beet leaf + walnut) bread

Parameter	Standard Whole Wheat Bread	Beet Leaf & Walnut Bread	Scientific Note
Energy value (kcal/100 g)	220–240	258.4	Higher energy density due to walnut and fat.
Protein (g/100 g)	7.5–8.2	8.2	Walnut plant proteins complement whole wheat flour.
Fat (g/100 g)	1.5–2.5	11.8	Rich in Omega-3 and unsaturated fatty acids.
Carbohydrate (g/100 g)	45–50	31.5	Lower carbohydrate load as flour amount is reduced.

Dietary fiber (g/100 g)	2.5–3.5	5.4	Twice the fiber content thanks to leaf fiber.
Vitamins & minerals	B_1, B_2, PP, Mg, Fe	A, C, B-group, Fe, Ca, K, Zn	Beet leaf provides advantage in Vitamin A, C and Calcium.
Glycemic Index (GI)	55–65 (Medium)	45–50 (Low)	High fiber and fat slow down carbohydrate absorption.
Antioxidant profile	Low / Medium	High	Due to betalains in leaf and polyphenols in walnut.

The comparative analysis shows that the proposed functional bread has a sharp advantage over standard whole wheat bread in terms of micronutrients (vitamin-mineral) and biologically active substances. The carbohydrate content of the product decreased by approximately 30%, while the dietary fiber content doubled; moreover, previous studies have shown that the incorporation of plant-based components enhances antioxidant properties and increases dietary fiber content compared to conventional whole wheat bread (Sławińska et al., 2022). Which proves its effectiveness in diabetic and dietary nutrition. In particular, the presence of Vitamins C and A, providing the product with anti-anemic and antioxidant properties, elevates it to a higher functional category than whole wheat bread. Comparative analysis and other studies also indicate that the enrichment of bread with plant-based functional additives has a positive effect on reducing its glycemic index and improving the digestion process (Liu et al., 2022).

Thus, both products complement each other: while whole wheat bread provides basic nutritional support, bread with beet leaf additive meets the requirements of modern dietary and healthy nutrition by increasing both nutritional and functional advantages. This comparison creates a scientific basis for strategic choices in both classic and functional bread production.

Conclusion

As a result of the research conducted, it was determined that whole wheat bread occupies an important place in daily nutrition by being rich in high energy and basic nutrients. The beet leaf additive, by increasing the vitamin, mineral, and antioxidant composition of bread, strengthens its functional food characteristics. The most optimal additive amount is considered to be 10–15%. At this point, both the nutritional value increases and the organoleptic characteristics are preserved. Thus, these two products, complementing each other, create a balanced nutritional source both in terms of energy and health, and are in line with the modern concept of healthy nutrition.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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