

Comprehensive Evaluation of Physicochemical and Sensory Properties of Bread Enriched with Natural Ingredients

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ABSTRACT

This study examines the physicochemical properties and energy value of bread produced using conventional baking technology and formulations enriched with whey, flaxseed, and wheat bran. Organoleptic evaluations were conducted to assess the impact of these natural additives on the sensory profile of the final product. The incorporation of whey, flaxseed, and bran significantly affected crumb moisture, titratable acidity, porosity, and macronutrient composition, including protein, fat, and carbohydrate content. Specifically, the enriched bread exhibited a crumb moisture content of 39.8%, titratable acidity of 4.9 °T, and porosity of 74.9%. Its energy value was calculated at 239.78 kcal per 100 g. Beyond improvements in taste and texture, the presence of bioactive compounds derived from both plant-based and animal-based ingredients enhanced the biological activity of the bread. The results support the classification of the enriched product as a functional food, with potential therapeutic, prophylactic, and preventive health benefits.

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Throughout history, food has been more than mere sustenance, it has been a cornerstone of human health, culture, and survival. Modern nutritional science increasingly emphasizes that food is not only a source of calories but also a vital medium for delivering bioactive compounds that regulate physiological processes and support disease prevention. Essential nutrients such as proteins, fats, and carbohydrates must be complemented by micronutrients and trace biologically active elements - including essential amino acids, vitamins, minerals, and phytochemicals - which play a decisive role in maintaining metabolic balance and long-term well-being [1].

As the global population navigates the challenges of the 21st century - ranging from chronic stress and emerging diseases to changing lifestyles-there is an urgent need to reformulate dietary practices with a focus on functionality. Consequently, the global scientific community has shifted its attention toward the development of functional food products, which go beyond basic nutrition to exert therapeutic or preventive effects on human health [2].

According to the World Health Organization, cardiovascular diseases and cancer remain the leading causes of death globally, accounting for nearly three-quarters of total mortality. This epidemiological reality has accelerated the search for natural food ingredients with preventive potential and the integration of such components into commonly consumed staples [2].

Among staple foods, bread occupies a unique and revered position. In many cultures and especially in Georgia-it is not only a daily necessity but also a cultural symbol. Georgian heritage highlights this through its traditional proverb: “*Bread is from Kartli, wine from Kakheti, cheese from Tusheti, and erbo* (traditional Georgian butter residue obtained by melting butterfat) from *Pshavi*.” Bread’s role as a foundational element of the human diet makes it an ideal candidate for nutritional enhancement and functional enrichment [1].

Modern food technology allows for the enrichment of bread with naturally derived compounds, such as plant-based phenolics, fibers, essential fatty acids, and minerals- which can enhance both its sensory characteristics and its health-promoting properties [3-5]. Studies have confirmed that supplementing bread with fruit, vegetable, dairy-based, or seed-derived ingredients can significantly increase antioxidant activity and contribute to meeting dietary needs that are often unmet in conventional diets [6-8]. Bread is a unique food product that contains nearly all components necessary for sustaining human life and health: proteins, complex carbohydrates, calcium, iron, phosphorus, and B vitamins, including thiamine, niacin, and riboflavin.

Beyond its nutritional role, bread is also a complex sensory product. Its organoleptic qualities- crust color, crumb structure, aroma, and flavor - determine not only consumer preference but also nutritional perception. Factors such as flour type, fermentation method, recipe formulation, and the addition of natural bioactive substances directly influence these characteristics. As a result, there is growing interest in designing bread not only as a palatable product but also as a functional delivery system for health-promoting ingredients [9-12].

It is well established that the combination of animal- and plant-based ingredients can enrich food products with biologically active substances. Among these, dairy by-products - most notably whey - represent some of the most promising raw materials for the development of multicomponent bakery products and for enhancing their biological value [13,14].

Equally promising is the use of plant-based ingredients such as flaxseed (*Linum usitatissimum*), which is distinguished by its rich nutritional profile and wide-ranging therapeutic properties. Flaxseed contains essential fatty acids, carbohydrates, proteins, fats, and a broad spectrum of vitamins, including A, B1, B2, B5, B6, C, E, and K. It is also an excellent source of calcium, magnesium, sodium, potassium, and phosphorus, as well as trace elements such as selenium. Importantly, it provides Omega-3, Omega-6, and Omega-9 fatty acids and demonstrates antibacterial, antiviral, and antifungal activities.

Moreover, flaxseed plays a regulatory role in the digestive system and is used as a diuretic, as well as in the management and prevention of constipation, diabetes mellitus, neoplasms, allergic disorders, and cardiovascular diseases, owing to its therapeutic and prophylactic potential [15-17].

Bran is a concentrated source of dietary fiber and serves as a key functional food component. Upon entering the gastrointestinal tract, it acts as an adsorbent. Although insoluble fiber is neither digested nor absorbed by the body, it functions by binding toxins, metabolic waste products, cholesterol, and heavy metals, thereby facilitating their elimination. Bran exhibits a wide range of health-promoting properties: it regulates gastrointestinal function, suppresses appetite, reduces blood cholesterol levels, and supports weight management. Regular consumption of bran enhances the body's resistance to disease, lowers blood glucose levels in individuals with diabetes, reduces arterial blood pressure, and offers therapeutic value in bile stasis, hepatic dysfunction, and constipation [18-22].

In light of the aforementioned, the inclusion of natural ingredients such as whey, flaxseed, and bran as functional additives appears both relevant and promising in bread production. These components contribute significantly to the nutritional enhancement and health-promoting potential of bread products.

Materials and Methods

The following materials were used as the objects of study:

1. Bread produced using standard technology (Control Sample III);
2. Dairy whey;
3. Bread enriched with natural ingredients (Sample II).

The primary focus of this research was bread enriched with dairy whey, flaxseed, and bran. The parameters assessed included crumb moisture content, crumb titratable acidity, and crumb porosity in both standard (control) and enriched bread samples (Table 5).

In addition, the organoleptic properties of both bread types were evaluated, including external appearance, loaf shape, crust surface, crumb structure, aroma, and taste. The results of the organoleptic evaluation are presented in Table 4.

All bread samples - both control and enriched variants - were prepared at the Agricultural Laboratory of Telavi State University named after Iakob Gogebashvili.

The first (control) sample was produced using the standard recipe and technological procedure, while the second (enriched) sample was made by incorporating dairy whey, flaxseed, and bran. All samples were prepared in strict accordance with the sequential steps and operational conditions defined by the relevant technological standards.

Table 1: Composition of Ingredients in Bread Baked Using Standard Technology

Ingredients	Control Sample I	Control Sample II	Control Sample III	Control Sample IV
Flour, g	1000	1000	1000	1000
Water, mL	400	600	700	1000
Water Temperature, °C	25	35	30	50
Natural Yeast, g	15	25	30	40
Salt, g	15	30	25	35

Based on the evaluation of organoleptic parameters, Control Sample III (see Table 1) was selected for further comparative analysis.

The technological scheme for baking bread enriched with natural ingredients consisted of the following stages: Production of whey using a traditional method; Preparation of a starter culture based on whey, followed by 12 hours of fermentation; Kneading of dough with the addition of flaxseed and bran; Resting of dough; Re-kneading (2–3 times); Dough dividing, shaping, and proofing; Baking; Cooling of bread; Sensory evaluation (tasting).

The chemical composition and organoleptic properties of the whey used in the formulation were also analyzed (Table 2).

Due to its high nutritional value and functional properties, whey represents a promising additive for bread formulation. Its incorporation not only enhances the nutritional profile of the product but also positively influences the leavening process and improves the overall quality and texture of the dough.

Table 2: Organoleptic and Chemical Parameters of Whey

Parameter	Value
Appearance and Consistency	Homogeneous, opaque liquid with slight sediment
Taste and Odor	Characteristic mildly sour taste with a slight sweetness and specific whey aroma
Color	Yellow with a greenish hue
Titrateable Acidity, °T	68
Energy Value, kcal	22.4
Proteins, g	1.2
Fats, g	0.4
Carbohydrates, g	3.5

Table 3: Ingredients of Bread Enriched with Natural Components – Whey, Flaxseed and Bran

Ingredients	Sample I	Sample II	Sample III	Sample IV
Flour, g	700	800	900	600
Bran, g	300	200	100	400
Whey, mL	100	600	150	300
Flaxseed, g	150	100	50	60
Water, mL	600	200	650	500
Water temperature, °C	35	30	25	45
Dry yeast, g	15	30	25	40
Salt, g	30	25	15	35

Table 4: Organoleptic Characteristics of Standard Bread and Bread Enriched with Whey, Flaxseed and Bran

Quality Indicators	Standard Bread (Baked with Standard Technology)	Bread Enriched with Whey, Flaxseed, and Bran
Shape and color	Corresponds to the shape of the baking mold; glossy surface with a light brown tint.	Corresponds to the shape of the baking mold; light brown tint.
Surface	Even, without cracks or splits. The upper crust is slightly domed.	Slightly uneven, with visible inclusions of flaxseeds on the surface.
Crumb Condition	Well-baked, elastic; returns to original shape after light finger pressure. No stickiness or sensation of moisture when touched. No voids or hardened areas. Pores are uniform and thin-walled.	Properly baked and dried; free from voids and hardened areas, with visible inclusions of flaxseeds.
Smell and taste	Distinct aroma characteristic of bread, free from foreign odors or tastes.	Aroma characteristic of bread with slightly sour notes, and a toasted grain aroma typical of flaxseed; free from foreign odors or tastes.

Table 5: Physicochemical Parameters and Energy Value of Standard Bread and Bread Enriched with Whey, Flaxseed and Wheat Bran

Parameters	Bread Baked by Standard Technology	Bread Enriched with Whey, Flaxseed, and Wheat Bran
Crumb Moisture, %	28.6	39.8
Crumb Acidity, degrees (°T)	2.0	4.9
Porosity, %	58.28	74.9
Proteins, g	9.0	9.5
Fats, g	1.3	3.86
Carbohydrates, g	43	41.76
Energy Value, (kcal/100g)	219.9	239.78

The research results demonstrated that bread baked using standard technology conformed to the typical loaf shape defined by the baking vessel, with only minor surface irregularities and no signs of crust burning. The bread was well-baked and elastic; when lightly pressed with a finger, it returned to its original shape without any stickiness or perceptible dampness. No voids or hardened areas were observed. The crumb featured uniform, thin-walled pores and exhibited a characteristic bread aroma and taste, free from off-odors or foreign flavors.

In contrast, the bread enriched with flaxseed distinguished itself through its savory sensory profile, characterized by a notable roasted grain aroma and flavor (Table 4, Figure 1).

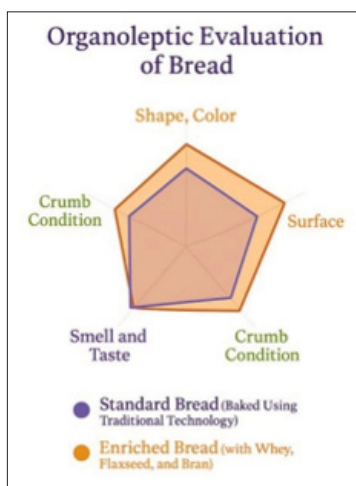


Figure 1: Organoleptic Profile of Bread Samples

The high dietary fiber content in flaxseeds enhances the bread's nutritional profile, while their vitamins, minerals, and phenolic compounds further contribute to its nutritional value and antioxidant potential. Whey imparts a subtle tanginess and a distinctive savory aroma to the baked bread. Flaxseeds and whey complement each other harmoniously, enriching the bread's natural flavor, while the addition of wheat bran contributes to a crisper texture. The combination of these ingredients results in a wholesome bread characterized by pronounced natural and savory sensory qualities.

Analysis of the physicochemical composition of bread samples baked using standard technology and those enriched with whey, flaxseeds, and wheat bran revealed that the inclusion of these natural components significantly affected crumb acidity, moisture content, porosity, and the levels of protein, fat, and carbohydrates, thereby influencing the overall energy value of the final product (Table 5, Figure 2).

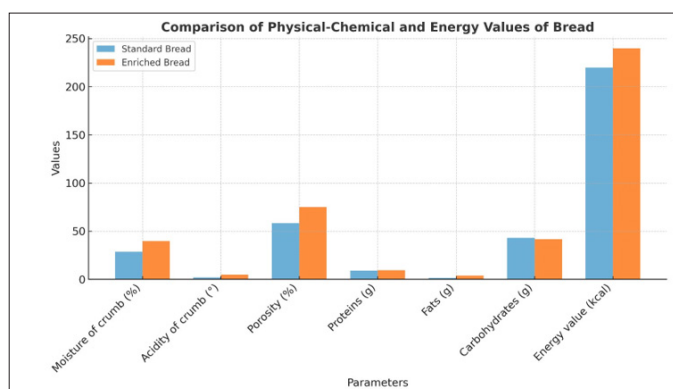


Figure 2: Physicochemical Parameters and Energy Value of Standard Bread and Bread Enriched with Whey, Flax Seeds, and Wheat Bran

Therefore, based on the study results, it can be concluded that the incorporation of whey, flaxseeds, and wheat bran is advisable for enhancing the nutritional value, improving quality parameters, refining sensory characteristics, and diversifying the bread assortment. The combination of animal-derived and plant-based raw materials in bread production yields a complementary effect-enhancing not only the sensory profile but also contributing synergistically to the overall nutritional value through the integration of beneficial compounds from diverse natural sources. Bread enriched with various natural additives, in

conjunction with other biologically active components inherent to the bread matrix, exhibits elevated biological activity and can thus be considered a functional product with therapeutic, prophylactic, and preventive potential.

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