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Article

Manufacture of High-Protein, Micronutrient Breakfast Cereals With Local Raw Materials and Their Physical and Chemical Characteristics

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Abstract: This study examined the manufacturing and testing of instant breakfast cereals to create high protein and micronutrient dense breakfast cereal with local raw materials since the additions resulted in an apparent change in the nutritional profile to elevate protein and fiber and reduce carbohydrates without altering the caloric value.ric content. It was also found that the physical, chemical and microbial characteristics of the product were within reasonable ranges and that there was a significant difference in crispness and shelf life. In contrast, sensory evaluation was negatively affected at high addition levels. Treatments T1 and T2 achieved the best balance between sensory acceptability and nutritional value, making the local product a promising healthy alternative compared to traditional commercial products. Relevance of the Study, aiding in the creation of nutritious food items rich in vitamins and protein and producing food items with excellent nutritional value by using local raw ingredients, as well as producing superior local substitutes to lessen reliance on imports. Encouraging research in the field of food science and the growth of regional food businesses. Offering food items appropriate for populations that need diets high in protein, such kids and athletes.

Keywords: Cereals, Functional Properties, Chemical Properties, Protein, Micronutrients, Vitamins, Minerals.

Introduction

Breakfast is taken as the nutritional foundation of the day and should supply about 300–500 kcal of energy. Hence, skipping breakfast heightens the risk of encountering challenges with attentiveness, metabolism, and weight management, given its role as the key meal or nutritional cornerstone of the day [1]. Furthermore, the use of local raw materials in food production contributes to supporting the local economy and reducing dependence on imported materials. In this context, this research focuses on the production of high-protein, micronutrient-rich breakfast cereals using readily available local raw materials, while studying their physical and chemical properties [2], and then comparing them with a commercially available product to assess their nutritional efficiency and quality. This research falls within the field of food science, which focuses on studying food components and methods to enhance their nutritional value. Over the last few decades, there has been a significant change in the food industry with an increased production of more functional foods combining high nutritional value and convenience and breakfast cereals are some of the most successful products in the

industry, with a high prevalence among the global population [3]. It is known that lysine and tryptophan are essential amino acids that are vital in body functions, which most maize breakfast cereals lack [4]. However, legume crops, are characterized by their richness in essential amino acids that are sulfur-containing as well and they are commonly used to supplement cereals products to enhance their nutritional value [5]. There are two types of breakfast cereals: traditional (hot) cereals, which require additional cooking or heating to be consumed and ready-to-eat (cold) ones, which may not need additional heating to be eaten [4].

Breakfast cereals are ready-to-eat foods, typically made from grains such as corn, wheat, and oats, and are often consumed with milk. These products are characterized by their ease of preparation, long shelf life, and the ability to fortify them with various nutrients [5]. However, many commercial products lack nutritional balance, as they contain low levels of protein and fiber, while being high in sugars. Protein is an essential nutrient for building tissue and supporting vital bodily functions. Traditional breakfast cereals are low in protein, which is why they are often fortified with plant-based protein sources [6]. The most important plant-based sources include soybeans, chickpeas, lentils, and millet. These sources are characterized by their high protein content, as well as essential amino acids. Studies have shown that combining legumes with grains improves the biological value of protein due to amino acid synergy [4], [5]. Micronutrients include vitamins and minerals that the body needs in small amounts but are essential for its vital functions, such as: iron (Fe), zinc (Zn), calcium (Ca), and vitamins (A, B, D). Physical properties have a great influence on the quality of products and their acceptance by consumers; hardness, brittle, density, and absorption of water are the most significant ones. Chemical analyses include an evaluation of the product's nutritional composition, such as protein, fat, moisture, ash, and fiber [6]. These analyses are used to determine nutritional value and compare it with commercial products. Comparison with commercial products is an essential step in evaluating the quality of the developed product, as it involves comparing nutritional value, physical properties, and sensory acceptance. This comparison aims to determine the new product's ability to compete in the market in terms of quality, price, and nutritional value [7].

Research Objectives

1. To produce breakfast cereals with high protein content and rich in micronutrients using local raw materials.
2. To study the physical properties of the product, such as texture, color, and crispness.
3. Analyzing the chemical properties of the produced flakes, such as protein, fat, carbohydrate, and moisture content.
4. Comparing the locally manufactured product with a commercial product available in the market.
5. Evaluating the feasibility of producing this type of breakfast cereal on an industrial scale

Materials
Flour
Chickpea flour
Powdered milk
Sesame flour
Walnut flour
Molasses
Vegetable oil
Cocoa
Vanilla
Water

Materials and Methods

The raw materials used in the manufacture of breakfast cereals are a key factor in determining the quality of the final product, both nutritionally and technologically. These materials are chosen based

on their availability locally, nutritional content, and their availability to the manufacturing processes. Certain physical and chemical characteristics are needed to guarantee a product with a satisfactory texture and properties.1 -Wheat Flour (Bashler Turkish) is one of the most popular types of flour and is also one of the most popular and widely used types, in the bakeries and home kitchens, particularly in Iraq.

1. One of the most well-known and extensively utilized varieties in bakeries and home kitchens, particularly in Iraq, is wheat flour (Bashler Turkish), a prominent Turkish brand in flour manufacturing. Because of its exquisite texture and remarkable purity, it is renowned for its superior quality and adaptability.
2. Chickpea flour Chickpea flour is a fantastic addition to breakfast cereals since it is high in plant-based protein, fiber, and vitamins and minerals including iron and zinc. Additionally, it raises the product's nutritional density and enhances its texture.
   Steps in Milling:
   - Remove any dust and contaminants from the chickpeas.
   - Clean the beans, soak them in water for a full day, and then let them air dry completely.
   - Use an electric grinder to ground the chickpeas into a fine powder.
   - To get a uniform particle size and eliminate coarse particles, sift the flour.
3. Usually prepared from a mixture of fresh milk and vegetable oils, millac milk powder is a multipurpose milk powder that may be purchased at local shops. Dairy goods, confections, and cuisine all make extensive use of it. It comes in a variety of forms that are appropriate for both home usage and business use in bakeries and restaurants.

Ground Walnuts: The walnuts were purchased raw from local markets and then ground using simple, readily available methods. This strategy was embraced instead of buying pre-made ground walnuts with the aim of saving money. The grinding process also aided in coming up with a relatively fresh product without compromising its nutritional qualities besides maintaining a satisfactory standard of hygiene and quality within the means at hand.

4. Ground sesame seeds of Pakistani origin: The sesame seeds were purchased raw from local markets and then ground using simple, readily available tools. This was done to acquire ground sesame in a feasible way and also at less cost than buying the prepared product. The grinding also assisted in giving a fairly fresh product, yet at the same time maintaining the nutritional value of the product, as well as ensuring a decent degree of hygiene and quality within their budget capabilities.
5. HORECA-grade vanilla was sold in the local markets; a form of vanilla extract, which is used commercially; it has a higher concentration and uniform flavor.
6. The HORECA-grade vanilla, which is a kind of vanilla extract meant for commercial usage and is distinguished by a higher concentration and consistent flavor, was bought from nearby stores. It is frequently used to add a strong and distinctive vanilla taste to cakes, pastries, and baked products.
7. Date syrup was purchased from local markets and used as a natural sweetener. Date syrup is a thick and sweet flavored foodstuff that is made by boiling the dates after squeezing out their juices and then concentrating it. It is found in making desserts and some foods, and helps to give them a natural level of sweetness and high nutritional value.8- ZER oil was bought at the local markets; it is a kind of vegetable oil that is used in cooking, and is characterized by light consistency and ability to be used in frying and cooking of food.
8. ZER oil, a sort of vegetable oil used in cooking that is suitable for frying and food preparation due to its light texture, was bought from local markets. Because it is simple to blend and has little effect on flavor, it is frequently used in food preparation and dessert preparation.
9. Spanish cocoa powder has been bought in local markets and it is regarded as one of the best varieties of raw cocoa consumed across the world especially in the confectionery and beverage sectors, as it has a uniform European quality and stringent production measures. It is made by grinding roasted cocoa beans, once cocoa butter is extracted out of them and comes in two primary forms, natural (light) and alkalized.

Method

1 This study relied on locally sourced raw materials readily available in the market, given their high nutritional quality and suitability for producing breakfast cereals with high nutritional value.
2 The ingredients used included wheat flour as the main component due to its good carbohydrate content and ease of shaping, as well as ground chickpeas to increase protein content and improve nutritional value, ground walnuts and ground sesame seeds to increase the content of healthy fats and minerals, as well as cocoa powder and vanilla to give the product an acceptable flavor and improve its sensory qualities.
3 It was also prepared using date syrup as a natural sweetener to add color and a characteristic flavor, oil to enhance the texture and feel in the mouth, and water to shape the dough and to regulate its water content.
4 Preparation was initiated by cleaning up of the raw materials in order to get out the impurities and undesirable elements to ensure the safety and quality of the end product.
5 Then, those ingredients that needed pre-grinding (e.g., chickpeas, walnuts, sesame seeds) were ground with the help of the right grinding machines to get a fine, homogenous powder that could be easily combined with other ingredients. Sifting of all powders was also carried out to guarantee homogeneity of the particle size and enhance the homogeneity of the mixture.
6 The next step involved weighing of the ingredients in predefined ratios in accordance with the formula followed in the study and thorough mixing of the dry ingredients to achieve a homogenous distribution of the nutritional elements.
7 Then liquid ingredients, water, molasses, and oil, were added in a gradual manner and continued to mix to arrive at a cohesive, homogeneous dough of the right consistency to shape.
8 At this point, the amount of water to be added was controlled to prevent too much moisture or dryness as this will directly impact the quality of the resulting wafers. Once the homogeneous dough was prepared, it was rolled and shaped into a desired shape and size to make breakfast wafers.
9 The flakes were then subjected to a heat treatment process, which is one of the fundamental stages of manufacturing, as it helps reduce moisture content, improve texture, and give the product the desired crispness.
10 This treatment also helps improve taste and extend shelf life. During the manufacturing process, a number of important operational factors were controlled, such as processing temperature, heating duration, and dough moisture content, given the significant impact these factors have on the physical and sensory characteristics of the final product, such as color, texture, taste, and overall appearance.
11 Collectively, these steps aimed to produce high-quality breakfast cereals with high nutritional value and good comparability to commercially available products on the market.

Table 1. Shows the weights for each transaction.

Test / Materials	T1 (g)	T2 (g)	T3 (g)	T4 (g)	T5 (g)
Flour	60	50	40	50	50
Chickpea flour	10	20	30	20	20
Powdered milk	8	8	8	8	8
Sesame flour	5	5	5	0	10
Walnut flour	0	0	0	10	0
Molasses	5	5	5	5	5
Vegetable oil	5	5	5	5	5
Cocoa	4	4	4	4	4

Vanilla	0.5	0.5	0.5	0.5	0.5
Water	2.5	2.5	2.5	2.5	2.5

Results

The results of physical and chemical analyses serve as a key indicator for evaluating the quality of the developed breakfast cereals and their ability to meet the desired nutritional goals. These analyses help determine physical characteristics such as texture and crispness, as well as chemical characteristics such as moisture, protein, and fat content, thereby aiding in the assessment of the product's nutritional value. Comparing the results with a similar commercial product also allows for determining the efficiency of the formulation used and the quality of the final product, and to provide a more accurate assessment of the local Cornflakes product. a comparison was conducted with the commercial product Choco Pops, which included sensory characteristics such as taste, texture, and color, as well as consumer acceptance. This comparison would aid in pointing out the strengths and weaknesses of every product and how much Cornflakes can compete in the local market.

Chemical Composition and Nutritional Value

The results of the chemical composition table indicate clear statistically significant differences among the various treatments in terms of moisture content, protein, fat, carbohydrates, and energy. The chemical composition and energy table 1 shows significant differences ($p > 0.05$) among the different treatments, with moisture content ranging from 4.12% to 6.50%, the lowest value recorded in treatment T1 (%4.12)and the highest in T3 and T4 (6.50%). The higher moisture content in the high-content treatments is attributed to the increased proportion of chickpea and sesame flours, which have a higher water-holding capacity due to their protein and fiber content. As for ash content, it ranged from 1.41% to 2.09%, with the highest value recorded in T5 (2.09%) and the lowest in T1 (1.41%).

Table 2. Shows the results of the chemical composition and nutritional value.

Treatment	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrates (%)	Energy (kcal/100g)
Control	5.70 ± 0.12^{c}	1.85 ± 0.08^{b}	10.18 ± 0.25^{c}	1.52 ± 0.07^{c}	80.21 ± 0.35^{a}	375.24 ± 1.10^{b}
T1	4.12 ± 0.10^{d}	1.41 ± 0.06^{c}	12.17 ± 0.22^{b}	1.63 ± 0.05^{bc}	79.43 ± 0.30^{a}	381.07 ± 1.25^{a}
T2	4.80 ± 0.15^{d}	1.44 ± 0.05^{c}	13.98 ± 0.30^{ab}	1.72 ± 0.06^{b}	76.67 ± 0.40^{b}	378.08 ± 1.05^{ab}
T3	6.50 ± 0.20^{a}	1.88 ± 0.09^{b}	14.79 ± 0.28^{a}	1.85 ± 0.08^{a}	74.15 ± 0.45^{c}	372.41 ± 1.30^{c}
T4	6.50 ± 0.18^{a}	1.47 ± 0.07^{c}	14.98 ± 0.26^{a}	1.77 ± 0.06^{b}	73.91 ± 0.50^{c}	371.49 ± 1.15^{c}
T5	6.20 ± 0.22^{b}	2.09 ± 0.10^{a}	14.96 ± 0.24^{a}	1.89 ± 0.07^{a}	73.41 ± 0.48^{c}	370.49 ± 1.20^{c}

Sensory Evaluation

The results of the sensory evaluation showed that treatment T1 was superior in all attributes (color, taste, aroma, texture, and overall acceptability) compared to the control and the other treatments. The results showed that treatment T1 was superior, recording the highest values in color (8.2), taste (8.0), Smell (8.1), texture (7.9), and general Properties (8.1), compared to the control, whose values ranged around (7.4–7.8). This is attributed to the fact that this treatment was closest in composition to

the standard model with a slight improvement in the ingredients. Sensory values gradually decreased in the higher treatments, with T5 recording the lowest values (overall acceptability 6.9). This is attributed to the increased proportions of chickpeas, sesame, and walnuts, which may impart strong or undesirable flavors, in addition to their effect on texture and color due to Maillard reactions during baking.

Table 3. Shows the results of the sensory assessment.

Treatment	Color	Taste	Smell	texture	General Properties
Control	7.8 ± 0.45^{b}	7.5 ± 0.50^{b}	7.6 ± 0.40^{b}	7.4 ± 0.55^{b}	7.6 ± 0.48^{b}
T1	8.2 ± 0.35^{a}	8.0 ± 0.42^{a}	8.1 ± 0.38^{a}	7.9 ± 0.46^{a}	8.1 ± 0.40^{a}
T2	7.9 ± 0.40^{ab}	7.8 ± 0.45^{ab}	7.7 ± 0.44^{ab}	7.6 ± 0.50^{ab}	7.8 ± 0.43^{ab}
T3	7.4 ± 0.55^{c}	7.2 ± 0.60^{c}	7.3 ± 0.52^{c}	7.1 ± 0.58^{c}	7.2 ± 0.54^{c}
T4	7.3 ± 0.60^{c}	7.1 ± 0.58^{c}	7.2 ± 0.50^{c}	7.0 ± 0.62^{c}	7.1 ± 0.57^{c}
T5	7.1 ± 0.65^{c}	6.9 ± 0.70^{c}	7.0 ± 0.60^{c}	6.8 ± 0.68^{c}	6.9 ± 0.66^{c}

Physicochemical Properties

The pH value decreased from 6.50 in the control to 6.28 in T5, indicating an increase in acidity, which rose from 0.25% to 0.36%. This is attributed to probiotic activity and organic acid production. The fiber content also increased from 1.80% to 3.10% due to the increased use of chickpea and sesame flour. Similarly, reducing sugars increased from 2.50% to 3.30% as a result of partial carbohydrate breakdown.

Table 4. Shows the results of the physicochemical properties.

Treatment	pH	Acidity (%)	Fiber (%)	Reducing Sugars (%)
Control	6.50 ± 0.05^{a}	0.25 ± 0.02^{c}	1.80 ± 0.10^{c}	2.50 ± 0.15^{c}
T1	6.45 ± 0.06^{a}	0.28 ± 0.03^{bc}	2.10 ± 0.12^{b}	2.70 ± 0.18^{bc}
T2	6.40 ± 0.07^{ab}	0.30 ± 0.02^{b}	2.40 ± 0.15^{b}	2.90 ± 0.20^{b}
T3	6.35 ± 0.05^{b}	0.33 ± 0.03^{ab}	2.80 ± 0.18^{a}	3.10 ± 0.22^{ab}
T4	6.30 ± 0.06^{b}	0.35 ± 0.04^{a}	3.00 ± 0.20^{a}	3.20 ± 0.25^{a}
T5	6.28 ± 0.05^{b}	0.36 ± 0.03^{a}	3.10 ± 0.22^{a}	3.30 ± 0.27^{a}
Treatment	**Total bacterial count**	**yeasts, molds**	**coliforms**	**Treatment**

Microbiological tests

The table of microbiological tests shows significant differences ($p>0.05$) between the treatments in the numbers of different microorganisms, as the total bacterial count (TVC) gradually increased from (2.10 log CFU/g) in the standard treatment to (3.10 log CFU/g) in the T5 treatment. This is attributed to the addition of probiotics, which are beneficial bacteria that directly contribute to increasing the total number, as well as the availability of a suitable nutrient environment for growth due to the inclusion of protein- and fat-rich ingredients in the treatments, such as chickpea flour, sesame, and walnuts. The results for yeasts and molds showed an increase from (1.80) in the standard treatment to (2.80) in treatment T5.

Table 5. Shows the results of the microbiological tests.

Treatment	Total bacterial count	yeasts, molds	coliforms
Control	2.10 ± 0.10^{c}	1.80 ± 0.08^{c}	0.90 ± 0.05^{c}
T1	2.30 ± 0.12^{bc}	2.00 ± 0.10^{bc}	1.10 ± 0.07^{bc}
T2	2.50 ± 0.15^{b}	2.20 ± 0.12^{b}	1.30 ± 0.08^{b}
T3	2.80 ± 0.18^{ab}	2.50 ± 0.15^{ab}	1.50 ± 0.10^{ab}

T4	3.00 ± 0.20[a]	2.70 ± 0.18[a]	1.70 ± 0.12[a]
T5	3.10 ± 0.22[a]	2.80 ± 0.20[a]	1.80 ± 0.15[a]
	p>0.05		

Discussion

The moisture content ranged from 4.12% to 6.50%, with treatment T1 having the lowest value (4.12%) and treatments T3 and T4 having the highest (6.50%), according to the chemical composition and energy table 1, which demonstrates significant variations ($p > 0.05$) across the various treatments. A previous study found that the increased percentage of chickpea and sesame flours, which have a better water-holding capacity because of their protein and fiber content, is responsible for the higher moisture content in the high-content treatments [8]. Ash content varied from 1.41% to 2.09%, with T5 having the highest value (2.09%) and T1having the lowest (1.41%). This is attributed to the increased mineral content resulting from the higher sesame content and the substitution of walnuts for sesame in treatment T5, as these ingredients are rich in minerals compared to flour [9]. Regarding protein, its percentage increased from 10.18% in the control treatment to 14.98% in T4 and 14.96% in T5, This is due to the increased amount of chickpea flour, which is a rich source of protein, in addition to the contribution of sesame and walnuts in raising this percentage [10]. As for the fat content, it increased gradually from 1.52% in the control sample to a peak of 1.89% in T5, This is attributed to the higher fat content in the walnuts used in this treatment, which led to an increase in the total fat content of the product. Conversely, the carbohydrate content decreased from (80.21%) in the control treatment to (73.41%) in T5. This is due to reducing the amount of flour (the main source of carbohydrates) and replacing it with protein- and fat-rich ingredients (chickpeas and walnuts) [11]. Energy ranged from (370.49–381.07 kcal/100g), with the highest value recorded in T1 (381.07) and the lowest in T5 (370.49), This is attributed to changes in the proportions of nutritional components, as the increase in protein and fat combined with the decrease in carbohydrates affected the total caloric value. This is attributed to the increased nutrient content in the samples, which provides a suitable medium for the growth of these microorganisms [12], in addition to the effect of the relatively high humidity in some treatments, which is an important factor in the growth of yeasts and molds. As for coliforms, they increased from (0.90) in the standard treatment to (1.80) in treatment T5. This may be attributed to an increase in the total microbial load due to the additives, or to manufacturing and handling conditions [13]. However, the values remained within acceptable limits, indicating that the product is still fit for consumption. In general, the increase in the numbers of bacteria, yeasts, molds, and coliforms is associated with an increase in the proportions of nutritional additives and probiotics, which lead to an improved environment conducive to the growth of microorganisms. These numbers remain within normal levels for food products, further incorporation of pigeon peas results into darker products that has low acceptability. Such product has increased crude fiber, protein, and ash content, but lower fat and carbohydrate content. Therefore, pigeon pea flour could be used as an important ingredient in improving the nutritional quality of breakfast cereals for consumption by both children and elderly population. This could therefore increase dietary intake of protein and minerals and contribute to eradication protein energy malnutrition and micronutrient difieciencies commom in developing counries. Efforts should therefore be made to diversify utilization of pigeon peas by incorporating in breakfast cereal formulations [14].

Conclusion

1 High-protein breakfast cereals can be successfully produced using local raw materials. The additions resulted in:
2 An increase in protein and fiber, a decrease in carbohydrates, and improved nutritional value.
3 Total energy was not significantly affected despite the change in composition.
4 Treatments T1 and T2 achieved the best balance between sensory quality and nutritional value.

5 The higher treatments (T4 and T5) improved nutritional value but negatively impacted sensory acceptability.
6 Fiber and plant-based ingredients contributed to improved microbial stability and extended shelf life.
7 The local product was nutritionally superior to the commercial product (higher protein and lower carbohydrates.

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