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Development of Cost-Effective and Nutritious Pesto: A Functional Food Incorporating Fermented Black Garlic and Roasted Walnuts

Ayesha Iftikhar[1], Rida Nazir[1], Saba Nadeem Dar[1*], Dua Fatima[1] and Hadiqa Tariq[1]

[1]Department of Nutrition and Dietetics, University of Management and Technology, Lahore, Pakistan

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***Corresponding Author:**
Saba Nadeem Dar
Department of Nutrition and Dietetics, University of Management and Technology, Lahore, Pakistan
sabadaar21@gmail.com

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ABSTRACT

Functional foods, besides mere nutrition, are also significant in promoting health. Fermented black garlic and walnuts are both rich in anti-oxidative bioactive substances that have cardio-protective properties. **Objectives:** The purpose of the study is to develop Nutri Pesto, a new functional pesto with the focus on roasted walnuts and fermented black garlic, and to review the nutritional content and antioxidant activity of the product. **Methods:** Nutri Pesto was developed by improving the sensory acceptability and the nutritional value by optimizing the ratios of the ingredients. The moisture, ash, protein, fat, fiber, and carbohydrate contents were determined using proximate analysis. Antioxidant activity was established by the DPPH antioxidant assay. There was a 16-panel hedonic test conducted using a 9-point scale on a sensory test. **Results:** Nutri Pesto had a great antioxidant activity based on bioactive compounds of fermented black garlic and walnuts. The proximate analysis report indicates that the pesto contains a dry matter of 70.80 percent, 29.20 percent moisture, 13.20 percent crude protein and 25.7 percent crude fiber, 55.90 percent fats and 3.63 percent ash, and 1.52 percent nitrogen-free extract. The sensory evaluation indicated an outstanding consumer acceptance with a taste, texture, and flavor of 7 or more on the 9-point scale. **Conclusions:** The proximate analysis revealed that pesto contained high amounts of macronutrients. The cost analysis showed that it is a good alternative to foreign products. Pesto has fermented black garlic and roasted walnuts that provide nutritional excellence to it, making it an interesting addition to the diet of health followers.

INTRODUCTION

Pesto is a fundamental and popular Staple of Italian cuisine, born in Genoa, the region of Liguria. It is normally made by using fresh basil, walnuts, garlic, olive oil, and Parmesan cheese, and mixed in a green sauce. A typical example of a Mediterranean dish is this sauce, which is a special blend of fresh and savory flavors. Nonetheless, with the tendencies of the culinary world moving to the experimentation of classic recipes, chefs have conducted numerous experiments with the traditional recipes by blending various ingredients such as herbs, nuts, and cheeses to come up with various iterations of the sauce [1]. The popularity of pesto has increased in recent years, with some interesting interpretations of the classical recipes. According to the International Food Information Council (IFIC), 60 percent of its customers are seeking such extra health benefits in the food. Fermented foods have increased by far the most increased to a level of 35% in the past decade, particularly due to their known benefits to the gut [2]. Besides this, the studies indicate that cardiovascular diseases cause approximately 32 per cent of the deaths in the world, which shows the need to maintain heart health constituents in the diet, such as walnuts and olive oil [3]. The ancient method, which is presently adopted in modern cuisine, fermentation

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improves nutritional values, taste, and digestive and intestinal health. The addition of fermented foods to foods with functional and nutrient-dense elements develops new and health-conscious menu items. Compared to raw garlic, fermented garlic is mild and sweet as well. Walnuts are a good source of antioxidants, omega-3 fatty acids, and necessary vitamins that help keep the heart and brain healthy [4]. The nutritional value is also enhanced because, with fermentation, the beneficial compounds, such as the S-allyl cysteine (SAC), which has myriads of health benefits, including cardiovascular system support and the immune system, are increased in their bioavailability [5]. It is a natural process that not only enhances the taste of food but also the texture, nutrition, and shelf life of each food. The application as a preservative led to the appreciation of fermentation based on the transformation of complex flavors, as well as improving the quality of food [6]. Preservation of food using the fermentation methods comes with numerous advantages over any other form, particularly in enriching the nutritional value of the food. One of the most influential advantages is the fact that anti-nutritive components, such as phytates in nuts and seeds, are possible to overcome and prevent the absorption of minerals. Fermented foods are more effective due to the presence of probiotics, which assist in gut health, improved digestion, and immunity [7]. Besides, fermentation can enhance the body's ability to absorb important nutrients while increasing the level of antioxidants, leading to improved health benefits such as protection from oxidative stress as well as the support of general health [8, 9]. Fermented black garlic illustrates the higher level of culinary skill produced by the isolation of a simple ingredient. In making black garlic, raw garlic is subjected to aging for about three weeks at a certain level of temperature and humidity, in which the bulbs acquire a black coloration, soft texture, and sweet umami flavor. Not only does garlic's taste change during the fermentation process, but its antioxidant level also increases. S-allyl cysteine is the most well-known bioactive, and it is found in black garlic. There are many known benefits of SAC, including powerful anti-inflammatory and antioxidant capabilities along with heart-protective effects [10,11]. In addition, black garlic is easier to digest than raw garlic because fermentation breaks down the sharp compound allicin. Putting fermented black garlic in pesto boosts its flavor by balancing the sweetness of garlic and the freshness of basil. This added ingredient makes the dish more complex while still being healthier and easier to digest, which is a plus for those sensitive to raw garlic [12]. Walnuts have been renowned for their wonderful nutritional benefits for years, including a very high source of omega-3, nutrition for the heart, and vitamins and minerals that every individual needs. Those nutrients promote the health of the heart, the brain, and the immune system. Walnuts are an equally abundant source of vitamin E, magnesium, folate, and antioxidants, which help in reducing oxidative stress and boosting immune support and cognitive functions [13, 14]. Like many nuts, walnuts also contain phytates that limit the bioavailability of some minerals such as iron, calcium, and zinc. Although this problem can be partially solved due to fermentation, which helps to break down phytates, thus making minerals more available in the body [15]. As the main herb in Filipino cuisine, Basil is considered a cornerstone of traditional and modern pesto. Its contribution to the bold sauce is in the form of fresh, peppery, and mildly sweet fragrance. Other than establishing the ideal flavor of the sauce, this scent herb is also nutritionally advantageous. The antioxidant property of this sauce is attributed to the presence of flavonoids and polyphenols [16]. In vegan and dairy-free diets, nutritional yeast, which has a cheesy and nutty taste, can be used as a vegan alternative to Parmesan cheese in pesto. Plant-based cooking tends to use a nutty flavor as an imitation of the savory taste. This alternative is high in the B vitamins, including B12, which is especially essential to vegans. Protein and fiber are also high in nutritional yeast, one that brings nutritional density to the pesto [17]. The lemon juice sprinkling is a refreshing touch to pesto, which is a good balance with the richness of the nuts and the oil. Citrus acidity is used to balance the savory taste of walnuts and garlic, which adds a fresh, clean contrast that supplements the overall flavor of the pesto and adds a dose of vitamin C, helping to boost immune function and protect the body against oxidative stress [18]. One of the main components of pesto is the extra virgin olive oil (EVOO), which is a supporting component and additionally provides its characteristic fruity flavor and slightly peppery flavor. In addition to being deliciously tasting, extra virgin olive oil contains numerous monounsaturated fats that are beneficial to the heart, and which also lower inflammation and cholesterol. Polyphenols, which are a form of antioxidant, are also present in EVOO and have been shown to have positive correlations with reduced risk of chronic disease. The hypothesis was that the fermented black garlic and roasted walnuts would improve the nutritional quality, antioxidant, and sensory characteristics of pesto.

The study aimed to develop *Nutri Pesto*, analyze its proximate composition, evaluate antioxidant potential and sensory acceptance, and compare its cost with a commercial product.

METHODS

This laboratory-based experimental study design was conducted in the University of Veterinary and Animal Sciences, Lahore after taking ethical consent. The study was conducted in 4 months from 18th November 2024 to 18th February 2025. This study aimed to formulate Nutri

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Pesto with functional ingredients, analyze its nutritional content, and ascertain its antioxidant activity and sensory acceptability. The net weight of Nutri pesto was 200g for a 100g recipe (Table 1).

Table 1: Demographic Status of the Surveyed Participants (n=270)

Ingredients	Amount
Fermented Black Garlic	10g
Roasted Walnuts	15g
Fresh Basil	20g
Olive Oil	40ml
Salt to Taste	According to Taste
Finely Grated Cheddar Cheese	1 tbsp

To begin with, the fresh bulbs of garlic were washed well to remove any dirt and impurities. They are then put in a fermentation chamber, where the temperature is meticulously maintained between 60°C to 70°C, and humidity levels are maintained at a comfortable 85 percent to 90 percent. This configuration provided the ideal conditions in which the fermentation of fruits was to occur during 2 to 3 weeks. After fermentation was completed, the garlic was crushed into a fine paste and kept in a sterile cover at room temperature to maintain its freshness until we were ready to use it in our pesto. Walnuts, being a vital part of our pesto, were roasted to bring about their taste. Then they are put in a convection oven at 180°C and left to cook for between 10 to 15 minutes. The walnuts were roasted and then allowed to cool down to room temperature, after which they were crushed into a coarse material in the food processor. Once this was done, everything was to be put in the food processor and mixed up. The pesto was stuffed in sterilized glass jars. Jars were then labeled after packaging. The sensory test gauges the pesto received as per taste, smell, feel, and appeal. 16 panelists undertook this test. They were told to rate the pesto on these four significant attributes on a 9-point Hedonic Scale in which 1 meant they disliked it very much, and 9 meant they liked it very much. Standard AOAC (2019) methods of moisture, ash, crude protein, crude fat, crude fiber, and nitrogen-free extract were used to analyze the Proximate composition of Nutri Pesto. Atwater factors were used to estimate energy value. The DPPH assay was used to determine the antioxidant activity of the pesto samples, as 0.1 M DPPH solution was added to the methanolic extracts of the pesto, incubated at 30 °C in the dark, and absorbance at 517 nm was measured to determine percentage inhibition and IC 50. The fresh leaves of basil were sprayed with running water, then allowed to air dry and mixed right away to maintain the aroma and the color. The price of all the ingredients was summed up and divided by the weight of the product to estimate the cost per serving and per gram, and compared with a commercial pesto brand to economically assess the product. To have a clear picture of the nutritional content of the pesto, proximate analysis was applied. This included a determination of protein, fat, carbohydrates, and fiber, which were determined by methods that are approved by AOAC (Association of Official Analytical Chemists). This discussion played a major role in defining the nutritional content of pesto. The capacity of the pesto to scavenge the free radicals, which gives an insight into its antioxidant prowess, was evaluated using the DPPH assay.

RESULTS

The calculation of the compositions per 15g portion indicates that Nutri Pesto is food rich in energy and nutrients, which is mainly composed of fats (8.4g) in the form of walnuts and olive oil. It is also a good source of dietary fiber (3.9g) and a moderate source of protein (2.0g), which substantiates its use as a functional food. Its concentrated nutrition is further described by the low moisture (4.4g) and carbohydrate (0.2g NFE) content (Table 2).

Table 2: Composition of Nutri Pesto

Nutrient	Value % /200g	Grams /200g	Grams /1g	Grams/ Serving (15g)
Dry Matter	70.80	141.60	0.708	10.6
Moisture	29.20	58.40	0.292	4.4
Crude Protein	13.20	26.40	0.132	2.0
Crude Fiber	25.75	51.50	0.258	3.9
Fats	55.90	111.80	0.559	8.4
Ash	3.63	7.26	0.036	0.5
Nitrogen Free Extract	1.52	3.04	0.015	0.2

The calculated caloric amount of 613.5 kcal/100g is largely determined by its high level of fat (503.1 kcal), which is healthy lipids of walnuts and olive oil. Dietary fiber (51.5 kcal) also plays a considerable role here, which emphasizes its health benefits to the gut. Such a calorie-rich profile establishes that Nutri Pesto is indeed a large source of calories made up of healthy ingredients (Table 3).

Table 3: Estimated Caloric Content Per 100g

Component	Mass per 100g (g)	Caloric Factor (kcal/g)	Calories (kcal)
Crude Protein	13.20	4	52.8
Fats	55.90	9	503.1
Crude Fiber	25.75	2	51.5
Nitrogen Free Extract	1.52	4	6.1
Total Calculated Energy	—	—	613.5

The dry, crude protein, crude fiber, fats, other ingredients, ash, and nitrogen-free extract of the pesto are 70.80, 29.20, 13.20, 25.7, 55.90, and 3.63 and 1.52, according to the proximal analysis report (Figure 1).

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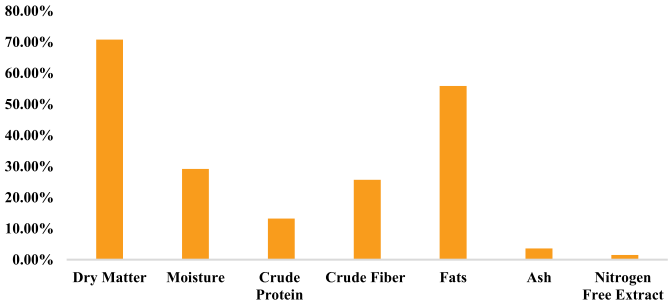

Figure 1: Proximate Analysis of Nutri Pesto

The antioxidant activity was determined using the DPPH assay. The inhibition of DPPH of 55.6% at 100 mg/mL concentration proves the applicability of Nutri Pesto in neutralising free radicals because of the bioactive compounds in fermented black garlic and walnuts. To be compared, the IC 50 of the two was computed to have [X] mg/mL (Table 4).

Table 4: DPPH Radical Scavenging Activity of Nutri Pesto

Parameters	Value
DPPH Radical Scavenging Activity	55.6 ± (SD) % inhibition
Test Concentration	100 mg/mL

The Nutri Pesto is 84.8 percent cheaper than Barilla, which gives it a far more cost-effective range. In addition, in another analysis, the Nutri Pesto costs 3.6 PKR per gram compared to the 23.69 PKR of Barilla. It is quite a terrific saving of over 6.58 times. This high difference indicates the cheap price of Nutri Pesto, which has high nutritional value and sensory characteristics. Nutri Pesto was also highly economical, with a cost of 720 PKR per 200g, when compared with Barilla Basil Pasta Sauce, whose cost was 13431 PKR per 567g (Table 5).

Table 4: DPPH Radical Scavenging Activity of Nutri Pesto

Products	Total Weight (g)	Total Cost (PKR)	Price per Serving (15g)	Price per g (PKR)
Nutri Pesto	200g	720	52.5 PKR	3.6
Barilla Basil Pesto	567g	13,431	355.35 PKR	23.69

Out of 16 panelists, 6 liked very much, 6 liked extremely, and 4 liked moderately (Figure 2).

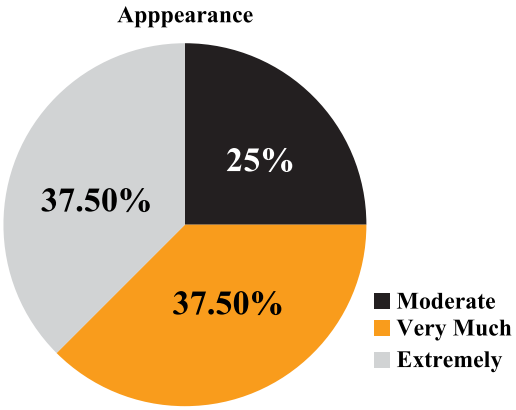

Figure 2: Appearance of Pesto

It was demonstrated that the number of panelists who liked, less preferred, preferred very much, and liked extremely was 9, 6, and 1, respectively (Figure 3).

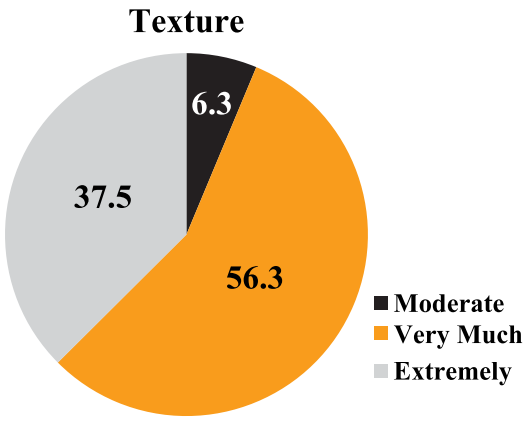

Figure 3: Texture of Pesto

Study demonstrates that 5 out of 16 panelists liked very much, 8 liked extremely, and 2 liked moderately (Figure 4).

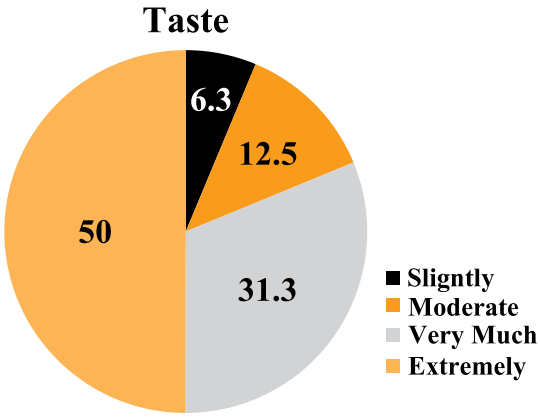

Figure 4: Taste of Pesto

Study demonstrates that 6 out of 16 panelists liked very much, 7 liked extremely, and 2 liked moderately (Figure 5).

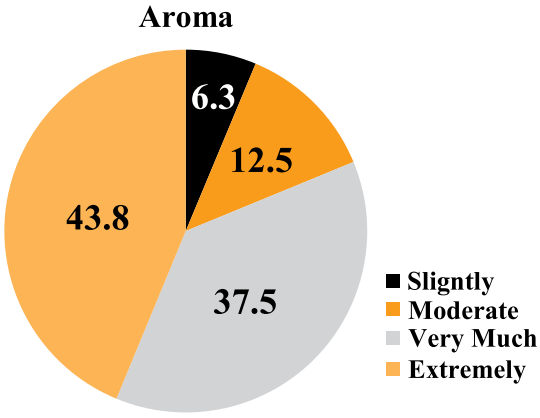

Figure 5: Aroma of Pesto

Study demonstrates that 5 out of 16 panelists liked very much, 8 liked extremely, and 2 liked moderately (Figure 6).

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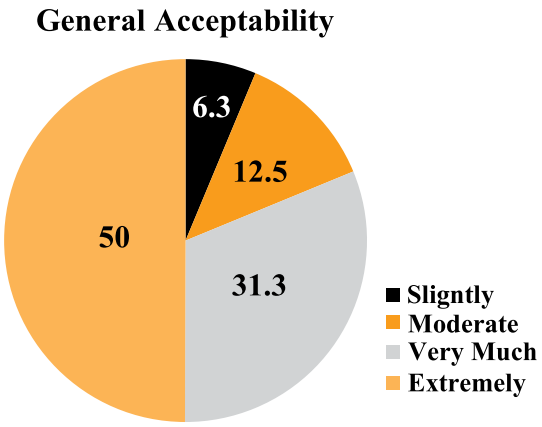

Figure 6: General Acceptability of Pesto

DISCUSSION

The results of formulating and conducting an analysis of Nutri Pesto revealed that it may be a promising functional food. The presence of several ingredients in the product that contain heart-healthy unsaturated fatty acids, particularly omega-3 and omega-6, like the walnuts and extra virgin olive oil in the product, led to the significant fat content (55.90) that was observed in the proximate analysis. It is known that consumption of such fats decreases the risk of cardiovascular diseases, enhances the functioning of the brain, and is also anti-inflammatory [18]. Protein content (13.20%) was also quite significant, and it was a resultant contribution of walnuts and nutritional yeast. This fact makes Nutri Pesto particularly attractive to vegetarians and people wishing to increase their consumption of plant protein [19]. Nutri Pesto also has high crude fiber content (25.75%), which is another distinguishing feature. Dietary fiber is associated with enhanced gastrointestinal health, better control of blood glucose levels, an increase in feelings of fullness, and aid in weight management [20]. Fermented black garlic is known to have both functional and sensory benefits, and adding it to the recipe of Nutri Pesto increases those benefits further [21]. As quoted, garlic fermentation augments its antioxidant potential by raising the level of S-allyl cysteine (SAC), a water-soluble molecule with strong antioxidant and cardioprotective effects [22]. An inhibition rate of 55.6% was achieved in the DPPH assay, which suggests potent free radical scavenging activities [23]. This also confirms the high antioxidant activities of Nutri Pesto, which stems from bioactive compounds in fermented black garlic, roasted walnuts, basil, and olive oil. Numerous studies have underlined the role of dietary antioxidants in the mitigation of oxidative stress and their relevance to the causative factors of chronic diseases such as cancer, diabetes, and cardiovascular diseases. From a sensory perspective, Nutri Pesto had higher acceptability scores in comparison to other forms of pesto according to the panelists. On the 9-point hedonic scale, all sensory parameters, which include taste, aroma, texture, and general acceptability, scored 7 and above. The highest scores were achieved in texture (8.31) and taste (8.25), which means that the synergistic effect of roasted walnuts and fermented garlic does improve the nutritional value of the product but also makes it enjoyable in mouthfeel and well-balanced in flavor. This supports the increased reported enjoyment of fermented food products owing to the umami taste, which develops during the aging process. From an economic perspective, the unit price was approximately 84.8 percent less than Barilla Basil Pesto. Availability of functional food products such as Nutri Pesto in low-resource contexts is enhanced by the fact that the local ingredients used to make the food are more sustainable and that the functional food products support sustainable food systems.

CONCLUSION

Finally, Nutri Pesto, which is based on fermented black garlic and roasted walnuts, exhibited good nutritional value, good antioxidant potential (55.6% DPPH inhibited), and good sensory acceptability. The product was an affordable functional food with better health benefits, as well as affordability compared to the commercial pesto.

Authors Contribution

Conceptualization: AA
Methodology: AA, RN, SND
Formal analysis: AA, SND, DF, HT
Writing review and editing: DF, HT

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

All the authors declare no conflict of interest.

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