



OPTIMIZING FORMULATIONS FOR BLACK RICE AND PEARL MILLET MUFFINS: BALANCING NUTRITION, TASTE, AND TEXTURE.

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Abstract: Muffins are formulated with black rice and pearl millet offer a nutritious alternative for cancer patients, addressing their dietary needs and to support weight gain. This study explores the development of optimized muffin formulation, replacing traditional ingredients such as refined flour, sugar, and butter with healthier alternatives. Black rice and pearl millet were selected for their high antioxidant content, protein, energy dense and micronutrients, which contribute to weight management and overall health benefits. Instead of refined flour, whole wheat flour was incorporated to enhance the fibre content and improve glycaemic response. Banana was included as a natural sweetener, reducing need for added sugars while providing essential vitamins and minerals. Peanut butter and coconut oil replaced conventional butter, offering healthy fats that support energy balance and immune function. Organoleptic evaluation was conducted to assess consumer perception regarding appearance, taste, aroma, and texture. This formulation aims to provide a functional food option that caters to the dietary needs of cancer patients, promoting better nutritional intake and overall well-being. The study highlights the potential of incorporating nutrient-rich ingredients in bakery products to create healthier, therapeutic alternatives for individuals with specific dietary requirements. Key words: black rice, pearl millet, muffins, dietary requirements and antioxidant.

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I. Introduction

According to ICAR-NCDIR (2021), non-communicable diseases account for 63% of total deaths in India, with cancer contributing 9%. Cancer results from the transformation of normal cells into malignant ones, often triggered by genetic and environmental factors, including exposure to carcinogens. Lifestyle and environmental risks such as tobacco use, alcohol consumption, unhealthy diets, physical inactivity, obesity, infections, and air pollution significantly contribute to cancer development. As per the Tamil Nadu Cancer Registry Project (2023) revealed approximately 88,750 cancer cases in Tamil Nadu in 2022. Chennai ranks sixth among Asian cities for breast cancer incidence. Perambalur district has the country's highest cervical cancer rate (32%), while Tiruvarur records the second-highest rate of oral cancer among women (8.9%). Erode, Coimbatore, and Tiruppur districts have the highest incidence of oesophageal cancer in men (6.8%). Cancer and its treatments often lead to complications, affecting various organs and causing symptoms such as anaemia, fatigue, cachexia, gastrointestinal issues, infections, pain, and neurological problems (National Institute of Health- National Cancer Institute, 2020). Comorbidities commonly associated with cancer include hypertension, diabetes, cardiovascular disorders, endocrine and psychiatric conditions, among others (Roy et al., 2018). To support cancer management, nutrient-rich and economical food products are being developed. One such approach is the formulation of muffins using black rice and pearl millet. The American Institute for Cancer Research (2023) recommends bakery items like oatmeal bites, fruit bars, and whole grain-based snacks for cancer prevention. Diets rich in fruits, vegetables, legumes, whole grains, and fermented foods—particularly those aligned with the Mediterranean diet—have shown potential in reducing cancer risk.

Black rice (*Oryza sativa* L.), primarily cultivated in Northeast India, and is rich in anthocyanin, iron, vitamin E, and dietary fibre. It exhibits strong antioxidant, anti-inflammatory, anti-cancer, and hypoglycaemic properties (Chanu, 2015; Ito & Lacerda, 2019; Bhardwaj et al., 2023). These compounds inhibit cancer cell proliferation, reduce oxidative stress, and support metabolic health. Pearl millet (*Pennisetum glaucum*) is recognized as a 'Nutri-Cereal' by the Indian government. It is a valuable source of protein, fibre, iron, zinc, phosphorus, and phenolic compounds. Pearl millet's high fibre content helps regulate blood sugar levels, making it suitable for diabetic patients, and its antioxidant properties contribute to cancer prevention (Nambiar et al., 2011; Satyavathi et al., 2021). Muffins, being widely accepted across age groups as a convenient snack or breakfast item, offer a promising medium for delivering therapeutic nutrition. Their spongy texture, palatability, and adaptability to healthy ingredients align with consumer trends favouring functional foods (Divyanshi et al., 2024; Chandra et al., 2022). Thus, the development of black rice and pearl

millet muffins aims to enhance the nutritional intake of cancer patients while supporting symptom management and improving overall well-being.

II. Methodology

2.1 Selection and Procurement of Raw Materials

The ingredients required for the formulated muffins were sourced from local market areas, as tabulated in the table.

Table 1- Selected main ingredients

S.NO	INGREDIENTS
1.	Black rice
2.	Pearl millet (kambu)

2.1.1. Selection of black rice:

When selecting black rice, check for a nutty and earthy smell. The texture should be firm, unbroken, and uniform in size. Prefer vacuum-sealed or airtight bags to prevent moisture contamination.

2.1.2. Selection of pearl millet:

The selection of kambu should include clean, uniform, and light greyish-green grains that are neither too dull nor too dark. The texture should be plump, firm, and uniform in size. The aroma should be mild and earthy. It should be free from contaminants such as dust, stones, and pests. Prefer vacuum-sealed or airtight containers.

2.1.3 Other Ingredients:

Additional ingredients such as sweeteners, leavening agents, fat sources, and flavour enhancers were procured based on standard food preparation guidelines to ensure optimal muffin formulation. Other ingredient like, egg, Peanut butter, Vanilla essence, Cinnamon powder, Baking powder and soda, Coconut, Coconut oil, jaggery and Flax seeds

2.2 Processing Techniques

2.2.1 Washing:

Black rice and pearl millet were washed thoroughly under running water to remove dirt, debris, and any surface contaminants. The grains were then spread on a clean cloth and air-dried to remove excess moisture before further processing.

2.2.2 Roasting

The dried grains were roasted on a low flame using a gas stove. The roasting temperature was maintained at approximately 110-120°C, ensuring even heating without burning. The grains were stirred continuously to achieve uniform roasting and prevent scorching. The roasted grains were then cooled at room temperature before grinding

2.2.3. Grinding and Sieving

The cleaned and dried black rice and pearl millet were finely ground using a commercial grinder. The ground flour was sieved through a fine mesh to ensure uniform particle size and remove any coarse particles. The final flour obtained was smooth, free of lumps, and had a consistent texture, ensuring better incorporation into the muffin batter. The finely sieved flour was stored in airtight containers to prevent moisture absorption and maintain its quality.

2.3 Standardization of Muffins Using Black Rice and Pearl Millet.

The product id formulated under four categories as control, variation 1, variation 2 and variation 3. The product formulated with both black rice and pearl millet after finely grounded. The standardization of the developed product is given in the table.

Table 2-Standardization of black rice and pearl millet muffins

Ingredients	Control	Variation 1	Variation 2	Variation 3
Wheat flour	100g	70g	60g	50g
Black rice	-	10g	15g	20g
Pearl millet	-	20g	25g	30g
Total	100g	100g	100g	100g

Plate 1 Standardized black rice and pearl millet muffins



2.4 Preparation of Muffins

In a large bowl, add baking soda and powder and other dry ingredients

In a bowl beat the egg till foam fat arises & add coconut oil, peanut butter and mix it well

Now add the coconut milk extracted from coconut mix well with whisker

Add the dry ingredients gradually and mix with spatula evenly and add seasonings

Now fill the batter in muffin cups by $\frac{3}{4}$ full and bake at 180° C for 20 minutes

2.5 Organoleptic Evaluation of Product

Sensory analysis of the food is examined with the human sense. Determine the organoleptic properties of the product. Sensory quality is combination of different sense of perception coming to play in choosing and eating a food. Appearance, flavor, mouth feel decide the acceptance of the food. (Srilakshmi, 2010).

Evaluation of texture involves measuring the response of a food when it is subjected to forces such as cutting, shearing, chewing, comprising, or stretching. Food texture depends on the rheological properties of the food. Subjective measurement of texture gives an indirect evaluation of the rheological properties of a food (Ramya and Anitha, 2020).

Using a nine-point hedonic rating system, the muffins in all variations had been evaluated organoleptically for quality aspects such as appearance, taste, texture, flavor, and overall acceptability. The study involved a total of 30 semi-trained panelists. To determine the most acceptable and consumable product, the average and standard deviation of the sensory assessment scores was calculated using Microsoft Excel 2013.

2.6 Nutritional Analysis of the Product

Determination of nutrients

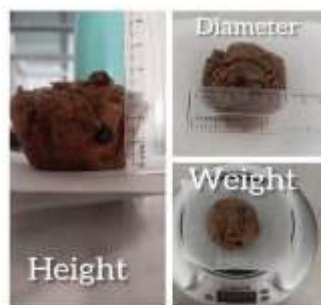
The Nutritive value of the ingredients were analysed by standard AOAC methods. The control and formulated muffins samples i.e. moisture content was determined adopting AOAC 2010 (Ramya and Anitha, 2020).

In food processing, from raw materials to the final product, chemical analysis of food is a crucial component of the quality assurance procedure. It is also important in formulating and developing new products. Nutrients like carbohydrate, protein, fat, energy, calcium, and iron were estimated.

2.7 Physical Parameters of the Product

Measurement of Weight, Height, Volume and Density: The muffins was weighed after cooling at room temperature for an hour. Using weighing balance and the reading (g) was recorded. The height (cm) of muffins was measured using ruler. Three measurements were taken from different sides of muffins. The average of the three points was recorded (Ramya and Anitha, 2020). Physical parameter like weight, height, diameter and radius of all the variations and control of the product is estimated.

Plate 3 Physical parameters of variation 2 developed muffins.



2.8 Physiochemical Analysis of the Product.

Determination of moisture and ash:

The muffins developed to gain weight of the cancer patients of control and the best variation is evaluated with moisture and ash.

Plate 4 Determination of ash and moisture of variation 2 developed muffins

(A) Indicates moisture of the sample (B) indicates Ash content of the sample

(A)

(B)



2.9 Shelf Life of the Product

To evaluate the phytochemicals and antioxidant activity and color stability in the newly formulated matrix, the samples were stored at a temperature of 25 °C for 21 days. At every seven days, the following parameters were measured: Total polyphenolic, flavonoids and anthocyanins content, antioxidant activity, color parameters and molds and yeasts (Croitoru et al., 2018). The shelf life of the product of the selected sample was determined by storing in an airtight container for 3 days of the storage. During storage period, the changes in moisture content, color, texture, and flavor were observed.

2.10 Packaging and Labelling Of the Product

The labelling of the product is in the form of image or verbal description of the product or the manufacturer. The label is identity of the product that describes ingredients, preservatives, name of the product, address of the product, nutritional content, and expiration date of the product. Packaging of a product is refers to the process of designing, evaluating and producing material for a newly product developed in a business that is marketed to the public.

2.11 Cost Calculation of the Product

The cost of 100g of developed muffin was done by calculating the cost of the raw material cost, packaging cost, overhead expenses, processing cost and profit. The developed muffins were economically feasible for the society. The detailed cost calculation is discussed in results and discussion

III. Results and discussion

3.1 Organoleptic Evaluation of Black Rice and Pearl Millet Muffins.

Organoleptic evaluation is also called as sensory evaluation, it is a subjective method of analysis used to assess sensory attributes of food and beverage through human senses. This focuses on taste, sight, smell and touch which determine the product quality and consumer acceptance. The formulated muffins were prepared and analyzed by 30 semi-panelist members by using hedonic rating scale. In this evaluation, the quality of the product were asked to judge by the panel members with respect to appearance, color, flavor, texture, taste and overall acceptability.

Sensory evaluation of formulated black rice and pearl millet muffins.

Mean scores of the sensory evaluation of the formulated muffins.

Table 3- Mean scores of the developed black rice and pearl millet muffins

Attributes	Control	V1	V2	V3
Colour	8.4	8.0	8.5	8.1
Appearance	8.1	7.2	8.5	7.1
Taste	7.8	7.4	8.4	7.5
Texture	7.6	7.7	8.5	7.5
Overall Acceptability	8.2	7.4	8.7	7.3

The above table indicates the average sensory score of the formulated black rice and pearl millet muffins. Among the three variations, second variation was highly accepted in all sensory characteristics. Variation 2 is accepted in all attributes when compared to the other two variations. Highly acceptable variation is variation 2 because the texture, taste, appearance, color is liked by the panel members.

The sensory comparison of various formulations (Control, V1, V2, and V3) was done on the basis of color, appearance, taste, texture, and overall acceptability, as shown in Table VI and Figure 4.1. The control sample recorded a maximum color score (8.4), followed by V2 (8.5), showing slight differences in visual appeal. Appearance scores indicated that V2 (8.5) outsourced all samples, including the control (8.1), perhaps because of differences in surface uniformity and ingredient interactions. The control (7.8) was most liked in taste, followed by V2 (8.4), indicating that the reformulation in V1 and V3 might have affected the taste.

Texture assessment indicated that V2 (8.5) was the best, while the control (7.6), were more or less similar but less rated. Overall acceptability scores showed that V2 (8.7) was the most preferred, followed by the control (8.2), and were lower rated. The better performance of V2 on several sensory parameters implies that it could be a good candidate as an alternative to the control product. The lower ratings of V1 and V3 imply that optimization of ingredients and processing conditions could improve their sensory properties.

3.2 Nutrient Analysis of the Black Rice and Pearl Millet Muffins

Black rice is enriched with iron, copper, fiber, and antioxidant. It is free from gluten, free of cholesterol, low and sugar, salt and fat. Pearl millet is the good source of energy, protein, carbohydrates, iron and fibers.

The proximate principle includes the nutrients like energy, carbohydrate, protein, fat, crude fiber, iron, copper and physiochemical properties like moisture and ash. The nutrient analysis of 100g of the formulated black rice and bajra muffins is the following tables.

3.2.1 Nutrient Analysis for the Formulated Black Rice and Pearl Millet Muffins

Nutrient analysis for acceptable variation of 100g

Table 4- Nutrient analysis of variation 2 muffins of 100g.

S.NO	PARAMETERS	NUTRITIVE VALUE
1	Energy	409.2kcal
2	Carbs	74.63g
3	Protein	4.36g
4	Fat	10.36g
5	Crude fiber	7.62g
6	Iron	927mg
7	Copper	1210mg

The proximate analysis nutritive value was interpreted in table 4. Formulation of muffins using black rice and bajra gives, primary source of carbohydrate, moderate energy, fats and high fiber, iron and copper, low protein contribution. The low carbohydrate content suggests that it may not be an immediate energy source but could be suitable for individuals following a low-carb diet. The moderate fat content contributes to essential bodily functions, while the protein content remains relatively low, necessitating supplementation from other sources for a balanced diet.

Table 5-Nutrient analysis for control of 100g

S.NO	PARAMETERS	NUTRITIVE VALUE
1	Energy	417.8kcal
2	Carbs	3.34g
3	Protein	3.43g
4	Fat	12.3g
5	Crude fiber	8.91g

The proximate analysis nutritive value of control was interpreted in table 5. The standard muffins gives, moderate energy, minimal source of energy form carbs, protein is low, moderate lipids and highlighted fiber. The low carbohydrate content suggests that it may not be an immediate energy source but could be suitable for individuals following a low-carb diet. The moderate fat content contributes to essential bodily functions, while the protein content remains relatively low, necessitating supplementation from other sources for a balanced diet. The sample appears to be a nutrient-dense food product with notable benefits for energy provision and digestive health.

3.2.2 Physiochemical Analysis of the Product.

Table 7 Determination of moisture and ash

Samples	Moisture (g)	Ash(g)
Control	10.02	0.92
Variation 2	32.3	10

The control sample had a moisture content of 10.02 g, while Variation 2 showed a much higher value of 32.3 g. This increase may be due to the water-holding capacity of ingredients like black rice or pearl millet flour, which can improve softness but may reduce shelf life. Ash content was 0.92 g in the control and significantly higher at 10 g in Variation 2, indicating a richer mineral content. This is likely due to the use of more nutrient-dense flours. Overall, Variation 2 appears to offer better nutritional value, though higher moisture may affect storage stability.

3.2.3 Physical Parameters of the Black Rice and Pearl Millet Muffins

Table 8-Physical parameters of product developed

Sample	Weight	Height	Diameter	Radius
Control	87	3	6	3
Variation 1	67	4	5.3	2.65
Variation 2	68	3	5	2.5
Variation 3	62	3.5	5.5	2.75

Physical features of the samples such as weight, height, diameter, and radius differed with respect to various formulations. From the table 8, the control sample had the greatest weight (87 g) and diameter (6 cm), while Variation 3 possessed the least weight (62 g). Variation 1 had the greatest height (4 cm), while the remaining variations measured between 3 cm and 3.5 cm. The variations in weight and size between the variations may be due to differences in ingredient composition, moisture level, and processing. The slight decrease in diameter and weight of the variations from the control might indicate differences in density, structural integrity,

or water retention ability. These results emphasize the effect of formulation changes on the physical characteristics of the product, which can affect consumer acceptability, texture, and product quality.

3.2.4 Shelf Life of the Formulated Black Rice and Pearl Millet Muffins.

The shelf life of the formulated black rice and pearl millet muffins was tested by storing the product under normal temperature. The shelf life can be analyzed by keeping the product under normal room temperature for 2 days to study the formulated black rice and pearl millet muffins and standard muffins.

The taste, texture, color, appearance of the sample black rice pearl millet muffin and standard wheat was acceptable on the 3rd day. The taste, texture, color and appearance of the formulated black rice and pearl millet muffins and standard wheat muffins was not acceptable as the taste was not nutty and earthy and the aroma of the muffins remained same.

3.3 Cost Calculation of the Black Rice and Pearl Millet Muffins

The cost of the black rice and pearl millet muffins is calculated according to the raw materials cost in the market. The cost of muffins for 100g has been calculated.

Table 9- Cost of variation 2 muffins

Product	Quantity (g)	Amount (Rs)
Black rice and pearl millet muffins	60	48

Cost calculation of the black rice and pearl millet muffins:

The production of Plastic cup made from polypropylene also known as PP were used and samples were stored in refrigeration temperature V2 has been identified by calculating all the ingredients and shown in the table 10.

Table 10- Cost calculation of ingredients added to prepare muffins

Ingredients	Quantity (g)	Amount (Rs.)
Wheat flour	60	4.44
Black rice	25	7.2
Pearl millet	15	0.9
Banana	100	13.2
Peanut butter	70	22.4
Coconut oil	40.8	34.2
Jaggery powder	45	3.96
Cinnamon powder	2.6	8.03
Vanilla extract	4.2	29.85
Egg	50	6
Baking powder	2.4	1.2
Baking soda	1.25	2.75
Flax seed	15	3.3
Coconut milk	62	30

- Cost of raw material: 27.905 rupees
- Overhead cost: 5 rupees
- Packaging and labelling: 16 rupees
- MRP of the product: 48 rupees
- The cost of V2 black rice and pearl millet muffins was computed by calculating the raw ingredient used for preparation of muffins.
- The product cost of 100g of muffins was Rs. 48.

3.4 Packaging of the Black Rice and Pearl Millet Muffins

Packaging and development of design plays a significant role in determining the shelf life of the good product. The right selection of packaging materials and technique maintains the product quality and freshness during distribution and storage. The pearl millet and black rice muffins were packaged in small plastic muffin cups to deliver convenience, ease of use, and freshness to consumers. The transparent style is customer-friendly and enhances product visibility, potentially boosting the appeal of the product to consumers. The package maintains texture to prevent moisture evaporation and ensures portion control. Even though it increases the cost of production, it enhances hygiene and presentation.

Plastic cup made from polypropylene also known as PP were used and samples were stored in refrigeration temperature.

3.5 Labelling Of the Black Rice and Pearl Millet Muffins

Plate 6 Labelling of the developed muffins



IV. Conclusion

The black rice and pearl millet muffins developed in this study were specifically formulated to support the nutritional needs of cancer patients. By incorporating ingredients rich in antioxidants, fiber, and essential minerals like iron and copper, the muffins offer potential benefits such as immune support, improved digestion, and reduced inflammation. Sensory evaluation confirmed that the optimized formulation (Variation 2) was well accepted in terms of taste, texture, and overall appeal, making it suitable for patients with altered appetite and taste sensitivities. The product was also found to be cost-effective and convenient, which is crucial for long-term dietary support. Although the shelf life was limited to two days at room temperature, proper packaging and refrigeration can help maintain product quality. These muffins not only serve as a nourishing and appealing dietary option but also highlight the role of functional foods in the dietary management of cancer, offering both therapeutic and economic value.

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