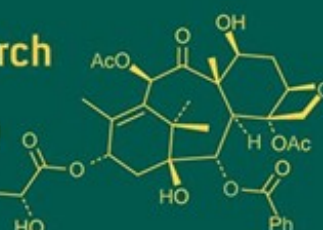
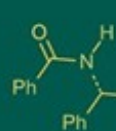
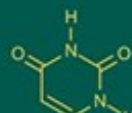


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Comprehensive nutritional, phytochemical and functional evaluation of sprouted black rice and its application in value-added product development

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ABSTRACT

The present study entitled “Comprehensive Nutritional, Phytochemical and Functional Evaluation of Sprouted Black Rice and Its Application in Value-Added Product Development” was undertaken to evaluate the nutritional potential of sprouted black rice flour and explore its application in the development of value-added functional food products. Black rice (*Oryza sativa* L.) is a pigmented cereal recognized for its nutritional value, dietary fibre, minerals, and bioactive compounds, particularly anthocyanins and phenolic compounds. Germination is an important processing technique that can modify the nutritional and functional characteristics of grains and enhance their potential for food applications. In the present study, black rice grains were cleaned, washed, soaked for approximately 12 h, and germinated for 48–72 h. The germinated grains were dried at 50–55 °C, milled, sieved, packed, and stored for further analysis. The prepared sprouted black rice flour was subsequently incorporated into four value-added products, namely sprouted black rice energy bar, chocolate, chocolate mousse, and smoothie, at progressively increased incorporation levels. The developed products were evaluated for proximate nutritional composition and energy value.

The sprouted black rice flour contained 9.68% protein, 3.66% fat, 5.45% crude fibre, 6.30% ash, 8.31% moisture, and 66.60% carbohydrate, with an energy value of 338.06 kcal/100 g. Progressive incorporation of sprouted black rice resulted in notable changes in the nutritional composition of the developed products. In the energy bar, protein increased from 11.5 to 14.5%, fat from 17.8 to 20.4%, fibre from 7.2 to 10.6%, ash from 3.1 to 6.4%, and carbohydrate from 51.9 to 72.5%, while energy values increased from 414 to 763 kcal/100 g. In sprouted black rice chocolate, protein increased from 8.5 to 11.5%, fat from 18.5 to 21.6%, fibre from 4.8 to 7.6%, ash from 3.2 to 6.7%, and carbohydrate from 57.5 to 80.6%, with energy values ranging from 430 to 765 kcal/100 g. Chocolate mousse showed increases in protein, fat, fibre, ash, and carbohydrate, with energy increasing from 347 to 692 kcal/100 g. Similarly, the smoothie exhibited increases in protein from 4.85 to 7.48% and fibre from 1.85 to 4.63%, with energy values increasing from 841 to 1262 kcal/100 g. Overall, the findings demonstrate the potential of sprouted black rice as a nutritionally valuable ingredient for the development of diverse value-added and functional food products.

Keywords: Sprouted black rice, *Oryza sativa* L., Germination, Sprouted black rice flour, Dietary fibre, Functional food, Value-added products

Introduction

Rice (*Oryza sativa* L.) is one of the most widely cultivated and consumed cereals and a staple food for more than 3.5 billion people worldwide. It plays a critical role in the daily diet in Asia, being an essential source of calories (Food and Agriculture Organization, 2022). Rice is an important crop in India, where it has cultural and commercial significance; however, the most popular variety of rice, namely, polished white rice, is deficient in several dietary fibers, vitamins, minerals, and phytochemicals (Pratiwi & Purwestri, 2017).

With the growing concern about the importance of the diet and the impact of nutrition on health and the increase in lifestyle-related diseases, such as diabetes, cardiovascular diseases, obesity, and cancer, there is a surge of interest in functional foods. Whole grain and colored rice, including red, brown, and black rice, have gained much attention in recent years due to their health benefits (Shahidi *et al.*, 2022). Black rice, also called forbidden rice, has been cultivated in Asia for centuries and traditionally eaten by the Chinese and Indian emperors for its health-promoting properties and is considered a functional food with high nutritional and health benefits (Ito & Lacerda, 2019).

The unique color of black rice is due to the content of flavonoid compounds called anthocyanins, which are water-soluble pigments with antioxidant activity. Anthocyanins are known to have numerous health benefits related to the reduction of oxidative stress, which is implicated in the development of many chronic diseases

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(Hou *et al.*, 2013). Compared to white rice, black rice contains a considerably higher amount of protein, fiber, essential amino acids, vitamins, and minerals. Moreover, compared to other colored rices, black rice has the highest contents of phenolic acids, flavonoids, anthocyanins, γ -oryzanol, tocopherols, and phytosterols. Cyanidin-3-glucoside is the major anthocyanin in black rice. The compounds that can be extracted from black rice have different biological activities, including antioxidant, *anti-inflammatory*, lipid-regulating, and glucose-modulating effects (Tiozon *et al.*, 2023).

Despite the high nutritional and health values, black rice is underutilized due to its hard texture, long cooking time, limited consumer acceptance, and low commercialization. Processing methods, including germination, can improve the nutritional and functional properties of rice. Germination or sprouting is a natural process of seeds' activation, leading to the conversion of complex nutrients into simple and more digestible forms (Aalim *et al.*, 2021). Sprouted rice is a healthy and nutrient-rich food with enhanced contents of phytochemicals and amino acids, as well as reduced levels of *anti-nutrients*, such as phytic acid. Sprouting can improve the bioavailability of different nutrients, for instance, minerals, such as iron and zinc, due to their increased content and better absorption. The method can also increase the concentration or bioaccessibility of phenolics, flavonoids, anthocyanins, and other phytochemicals and thus improve the antioxidant activity of rice (Shahidi *et al.*, 2022).

Sprouted black rice can be used as an ingredient in various food products, including baked goods, confectionery products, cookies, cakes, energy bars, snacks, functional beverages, porridge, and fermented foods. Functional foods made from sprouted black rice will have improved nutritional properties and can be used to increase the intake of fiber, minerals, vitamins, and phytochemicals. Sprouted black rice can be a good addition to the daily diet, as it helps improve digestion and has antioxidant activities. The development and application of such functional foods would be beneficial for the people of India and the local business since it can help create a new market for the export of India's local black rice, particularly from northeastern states. Thus, it is essential to study the nutritional, physicochemical, functional, phytochemical, and antioxidant properties of sprouted black rice to develop new rice-based healthy functional foods with desirable quality.

Materials and methods

Formulation of various value added products with the help of sprouted black rice flour. Four types of products were formulated with different levels of incorporation of sprouted black rice flour. The

products were: Sprouted Black rice smoothie, Sprouted black rice Chocolate, Sprouted black rice Chocolate mousse, Sprouted black rice energy bar. After formulation, the products underwent nutritional analysis and energy calculation.

Procurement of raw materials

Black rice was procured from an agricultural supplier in the vicinity. The other raw materials used in the study were procured fresh from the local markets in Kanpur. After procurement, the black rice grains were stored in air tight containers.

Preparation of sprouted black rice flour

The black rice grains were procured and cleaned and sorted to remove foreign matters, damaged grains and other impurities. The cleaned grains were properly washed and soaked in water for about 12 hours to allow hydration and germination to take place. These soaked grains were later drained and germinated for about 48-72 hrs to allow germination process to commence. Thereafter, the sprouted black rice grains were dried at 50-55 °C to reduce moisture content to an acceptable level. The dried sprouted black rice grains were crushed to form a fine powder and sieved appropriately. The resultant sprouted black rice flour was then properly packed into suitable packing material and stored under recommended conditions for further analysis and utilization in the production of value added food products.

Developed energy bar from sprouted black rice flour

Method:

- Roast the sprouted black rice flour lightly on low heat.
- Roast the seed mix and dry fruits separately and chop them finely.
- Remove seeds from the dates and make a smooth paste.
- Heat ghee in a pan and add the date paste; cook it briefly until it becomes soft and sticky.
- Add the roasted sprouted black rice flour, seed mix and dry fruits to it.
- Gradually add milk and mix until a thick, cohesive mixture is formed.
- Transfer it to a greased tray and press it firmly to get uniform thickness.
- Allow it to cool and set, then cut into energy-bar pieces.

Sprouted Black Rice Energy Bar

Ingredients (g/100 g mix)	Control (C)	T1	T2	T3	T4
Sprouted black rice flour	0	20	30	40	50
Milk	20	20	20	20	20
Dates (sweetener)	35	30	25	20	15
Ghee	10	10	10	10	10
Seed mix	15	10	10	5	0
Dry fruits mix	10	5	5	5	5
Roasted channa powder	10	5	0	0	0
Total	100	100	100	100	100

Developed chocolate mousse from sprouted black rice flour

Sprouted Black Rice Chocolate Mousse

Ingredients (g/100 g mix)	Control (C)	T1	T2	T3	T4
Sprouted Black Rice Slurry (g)	0	10	20	30	40
Milk powder (g)	35	35	20	15	10
Cocoa Powder (g)	20	20	15	15	15

(continued on next page)

Sprouted Black Rice Chocolate Mousse

Dark chocolate (g)	25	25	25	25	25
Dates Paste (g)	15	15	15	15	15
Roasted <i>Channa</i> Powder (g)	5	0	0	0	0
Total	100	100	100	100	100

Method:

- Prepare the sprouted black rice slurry by grinding properly sprouted and cooked/softened black rice with a little water till it is smooth.
- Soak the dates and blend into a smooth paste.
- Melt the butter gently in a double boiler or on low flame.
- Add the sprouted black rice slurry, milk, cocoa powder, dates paste and roasted channa powder to the melted butter. Mix continuously on low flame till it becomes smooth.
- Once off the flame, allow the mixture to cool down for a while.
- Whisk or blend the mixture till it is smooth, creamy and mousse like in consistency.
- Pour into serving cups and refrigerate for 2-4 hours for it to set.
- Serve chilled.

Procedure for determining moisture content**Principle**

Moisture content was determined using the hot-air oven method based on the principle of weight loss after drying.

Apparatus

- Hot-air oven
- Moisture dishes
- Desiccators
- Analytical balance

Procedure

Approximately 5 g of the sample was weighed and placed in a pre-dried moisture dish. The moisture dish was then placed in a hot-air oven set at $105 \pm 2^\circ\text{C}$ and left until a constant weight was recorded. The dish was then cooled in the desiccators and reweighed.

Calculation

- W_1 = Weight of sample before drying (g)
- W_2 = Weight of sample after drying (g)

$$\text{Nitrogen (\%)} = \frac{(V_1 - V_2) \times N \times 14.007 \times 100}{W \times 1000}$$

Therefore,

$$\text{Protein (\%)} = \frac{[(V_1 - V_2) \times N \times 14.007 \times 100 \times 6.25]}{W \times 1000}$$

Where:

- Protein Content (%)
- $\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$
- V_1 = Sample titre value (mL)
- V_2 = Blank titre value (mL)
- N = Normality of acid
- W = Weight of sample (g)

Procedure for determining crude fat**Method: Soxhlet Extraction****Principle**

Crude fat was determined using the Soxhlet extraction method, which involves extracting fat from the sample using petroleum ether.

$$\text{Moisture (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Procedure for determining crude protein**Method: Kjeldahl Method (AOAC)****Principle**

- Protein content was determined based on the nitrogen content of the sample.
- The organic nitrogen in the sample was digested to form ammonium sulphate.
- The ammonia gas released from the digested sample was trapped in a boric acid solution and titrated against standard hydrochloric acid.
- The nitrogen content was then converted to protein content using a conversion factor.

Apparatus

- Kjeldahl digestion unit
- Distillation apparatus
- Burette
- Conical flask

Procedure

- A weighed sample was digested with concentrated sulphuric acid using a catalyst until a clear solution was obtained.
- The solution was diluted with distilled water and transferred to the distillation unit.
- Sodium hydroxide solution was added to release ammonia gas, which was trapped in the boric acid solution.
- The solution was then titrated against standard hydrochloric acid.

Calculation**Apparatus**

- Solvent extractor
- Conical flasks

Procedure

- A weighed sample was placed in a thimble and inserted into the solvent extractor.
- Petroleum ether was then passed through the sample until fat was completely extracted.
- The solvent was then evaporated, and the fat was weighed.

Calculation

$$(W_2 - W_1) \times 100$$

$$\text{Fat Content (\%)} = \frac{W}{W_2 - W_1} \times 100$$

Where:

- W_1 = Weight of empty extraction flask (g)
- W_2 = Weight of flask + extracted fat (g)
- W = Weight of sample taken for analysis (g)

Procedure for determining ash content**Principle**

- Ash content indicates the total amount of minerals present in the sample.
- The sample was burned in a muffle furnace at 550 °C until all the organic matter was removed, leaving behind the inorganic minerals.

Apparatus

- Muffle furnace
- Silica crucibles

Procedure

- Approximately 2-5 g of the sample was weighed and placed in a pre-weighed silica crucible.
- The crucible was then placed in a muffle furnace at 550 °C until light grey ash was obtained.
- The crucible was then cooled in a desiccator and reweighed.

Calculation

$$\text{Ash Content (\%)} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

$$\text{Carbohydrate (\%)} = 100 - [\text{Moisture (\%)} + \text{Protein (\%)} + \text{Fat (\%)} + \text{Ash (\%)} + \text{Crude Fiber (\%)}]$$

Where:

- M = Moisture (%)
- P = Protein (%)
- F = Fat (%)
- A = Ash (%)

Where:

- Protein = 4 kcal/g
- Fat = 9 kcal/g
- Carbohydrate = 4 kcal/g

Result and discussion

Proximate composition Sprouted black rice flour (in 100g):

Proximate composition of the developed sprouted black rice flour is presented in Table 1. It can be noted that the obtained flour contained 9.68% protein, 3.66% energy value of 338.06 kcal/100 g. It can be concluded that this type of flour is primarily a source of carbohydrate with significant content of protein and fibre, fat, 5.45% crude fibre, 6.30% ash, 8.31% moisture and 66.60% carbohydrate with an estimated. The moisture content of 8.31% indicates that the product was sufficiently dried, which would prevent microbial contamination and deterioration.

The protein content of the obtained flour was relatively high, being 9.68%. It suggests that the product can be used as an ingredient increasing the protein content of food products. The process of germination

Where,

- W_1 = Weight of empty crucible (g)
- W_2 = Weight of crucible + sample before ashing (g)
- W_3 = Weight of crucible + ash after ashing (g)

Procedure for determining crude fibre**Principle**

Crude fibre is determined by boiling the sample in dilute sulphuric acid followed by boiling in dilute sodium hydroxide solution.

Apparatus

- Distilled water
- Sulphuric acid
- Sodium hydroxide solution

Procedure

- The sample was boiled in dilute sulphuric acid and then transferred to a boiling mixture of dilute sodium hydroxide solution.
- The solution was filtered, washed, dried, and incinerated to determine the weight of crude fibre.

Calculation

$$(W_2 - W_3)$$

$$\text{Crude Fiber (\%)} = \frac{W_2 - W_3}{W_1} \times 100$$

$$W_1$$

Where:

- W_1 = Weight of sample taken (g)
- W_2 = Weight of crucible + dried residue after acid and alkali digestion (g)
- W_3 = Weight of crucible + ash after ignition (g)

Procedure for determining carbohydrate content

Carbohydrate content was calculated using the difference method.

Calculation

- CF = Crude Fiber (%)

Procedure for determining energy value

The energy value was determined using the Atwater conversion factors. Protein, carbohydrate, and fat contents were used to calculate the energy value using the formula below:

$$\text{Energy (kcal/100 g)} = (4 \times \% \text{ Protein}) + (9 \times \% \text{ Fat}) + (4 \times \% \text{ Carbohydrate})$$

nation leads to the activation of hydrolytic enzymes and changes in nitrogen metabolism. According to Moongngarm *et al.* (2010) [1], germination increases the level of protein and free amino acids in rice due to biochemical transformations. Recent research has also confirmed that germination can lead to significant increases in protein content in rice, which depend on the variety and growing conditions. The content of fat in the obtained flour was relatively low, being 3.66%. This level can be considered typical for cereal flours, but it suggests the significant contribution of lipids to the energy value of the product. The level of crude fibre in sprouted black rice flour was 5.45%. This content was relatively high compared to other nutritional components, which is positive for the nutritional properties of the product. The literature data indicates that germination can lead to increases in the dietary fibre content of rice.

The content of ash in the obtained flour was comparatively high, being 6.30%. It suggests that the sprouted black rice flour contains significant levels of minerals. Black rice is a cereal with relatively high levels of various nutrients, especially in the outer layer. The content of carbohydrate in the obtained flour was relatively high, being 66.60%. The content of carbohydrate in the developed flour was the

highest among all nutritional components. Germination can lead to significant changes in the starch characteristics due to the action of various hydrolytic enzymes. The enzyme α -amylase can catalyse the hydrolysis of starch into sugars, which is required for grain germination and growth. According to the literature data, the process of germination leads to changes in the content and composition of carbohydrates in rice. The estimated energy value of the developed flour was 338.06 kcal/100 g. It can be concluded that the sprouted black rice flour can be used as an ingredient increasing the content of carbohydrates, protein and fibre in the diet.

It can be concluded that the proximate composition of the developed sprouted black rice flour was relatively high in terms of nutritional components. However, the product can be classified as a source of carbohydrates with moderate contents of protein and fibre. Sprouted black rice is a nutrient-rich cereal, and it can be used for the development of functional foods and new products. Besides the proximate nutritional components, black rice contains various bioactive substances, especially in the outer layer. The process of germination can also affect the content and availability of various bioactive compounds in black rice, which varies depending on the variety and conditions of germination.

Proximate composition of the developed sprouted black rice energy bar (in 100 g):

The proximate composition of the developed sprouted black rice energy bar showed an increase in the content of most nutritional components from E_{T1} to E_{T4} . In particular, the protein content increased from 11.5% in E_{T1} to 14.5% in E_{T4} . This suggests that the successive formulations contained higher levels of protein, increasing by approximately 26.1%. This can be explained by the introduction of ingredients rich in this component, including roasted chana powder, seeds and dry fruits. The process of germination can also affect the content of protein in the product, since it can activate hydrolytic enzymes and proteolytic processes. According to [Ikram et al. \(2021\) \[2\]](#), germination leads to changes in protein fractions and the formation of more available amino acids in different cereals, depending on the variety and technology.

The fat content in the developed energy bar also increased from 17.8% (E_{T1}) to 20.4% (E_{T4}). This can be associated with the introduction of a higher amount of seeds, nuts/dry fruits and ghee in the successive formulations. Fat is one of the most energetically valuable components, providing approximately 9 kcal per gram. It can be seen that the fat content in the developed energy bar was relatively high, which indicates a significant contribution to the energy value of the product. The increase in this component from E_{T1} to E_{T4} was gradual, which suggests that the successive formulations became richer in fat. This might have made the formulations more caloric and energy-dense.

The dietary fibre content increased gradually from 7.2% in E_{T1} to 10.6% in E_{T4} , which indicates that the successive formulations were also richer in this component. The increase was relatively significant, being around 47.2%. The literature data indicates that dietary fibre is positively associated with satiety and healthy digestion. The process of germination can also affect the dietary fibre content, which depends on the variety and technology. According to [Stagnari et al. \(2019\) \[3\]](#), germination leads to changes in the composition and properties of dietary fibre in cereals. The increase in fibre content from E_{T1} to E_{T4} could also be associated with the higher amount of sprouted black rice, seeds, dry fruits and roasted chana introduced into the formulations.

The ash content increased from 3.1% in E_{T1} to 6.4% in E_{T4} , which suggests that the successive formulations contained higher levels of minerals. The moisture content also increased gradually, from 8.5% in E_{T1} to 10.6% in E_{T4} . The relatively small increase in this component can be considered a positive trend for the investigated formulations. It can be seen that the moisture content was relatively low in comparison with many other products, particularly those with high-fat content. This suggests that the developed formulations could be charac-

terized by good stability and a long shelf life under appropriate storage conditions.

The content of carbohydrate in the developed energy bar increased significantly from 51.9% in E_{T1} to 72.5% in E_{T4} . This can be explained by the relatively high content of this component in sprouted black rice, dates and dry fruits, which were used as main ingredients. Carbohydrate is another component that is energetically valuable, providing 4 kcal per gram. The increase in the content of this component from E_{T1} to E_{T4} suggests that the successive formulations were richer in carbohydrate. The relatively high levels of carbohydrate, fat and protein in the developed energy bar indicated that the product could be caloric and energy-dense.

The corresponding energy values were 414 kcal for E_{T1} , 531 kcal for E_{T2} , and 635 kcal for E_{T3} ; however, it was not possible to determine the energy value for E_{T4} based on the provided data in [Table 2](#). In addition, according to the Atwater factors, the reported proximate composition of the formulations should also indicate the energy values, since protein and carbohydrate provide 4 kcal per gram, while fat provides 9 kcal per gram. It was found that some of the indicated energy values did not correspond to the proximate composition of the formulations. Therefore, before submitting the thesis, it is necessary to recalculate the energy values of the formulations using the Atwater factors, which would enable obtaining accurate results. It can be seen that the successive formulations of the energy bar were characterized by relatively high increases in the content of protein, fat, fibre, ash and carbohydrate.

Proximate composition of the developed sprouted black rice chocolate mousse (in 100 g):

The proximate composition of the developed sprouted black rice chocolate mousse showed an increase in the levels of most nutritional components from C_{MT1} to C_{MT4} showed in [Table 3](#). In particular, the protein content increased from 6.8% in C_{MT1} to 9.5% in C_{MT4} . This suggests that the successive formulations contained higher levels of protein, increasing by approximately 39.7%. This can be explained by the introduction of ingredients rich in this component, including sprouted black rice slurry and milk. The process of germination can increase the content of protein in the product, since it activates hydrolytic enzymes and proteolytic processes. According to [Lemmens et al. \(2019\) \[4\]](#), germination leads to changes in protein fractions and technological properties of different cereals. Sprouting is considered a promising technology for improving the nutritional and functional properties of cereal products ([Ikram et al., 2021\) \[2\]](#).

The fat content in the developed chocolate mousse also increased from 14.5% in C_{MT1} to 17.5% in C_{MT4} . This can be associated with the relatively high content of this component in the butter and cocoa powder used as ingredients. It can be seen that the fat content was relatively high for the developed formulations of sprouted black rice chocolate mousse, which made them caloric and energy-dense. The increase in this component from C_{MT1} to C_{MT4} was gradual, suggesting that the successive formulations became progressively richer in fat.

The dietary fibre content increased gradually from 6.2% in C_{MT1} to 9.6% in C_{MT4} , which indicates that the successive formulations were also richer in this component. The increase was relatively significant, being around 54.8%. The literature data indicates that a relatively high content of dietary fibre is associated with healthy digestion and increased satiety. The process of germination can also affect the dietary fibre content, which depends on the variety and technology. According to [Stagnari et al. \(2019\) \[3\]](#), germination leads to significant biochemical changes in cereals, including changes in the composition and properties of dietary fibre. The increase in fibre content from C_{MT1} to C_{MT4} could also be associated with the higher amount of sprouted black rice slurry introduced into the formulations.

The ash content increased from 2.1% in C_{MT1} to 5.7% in C_{MT4} , indicating that the successive formulations contained higher levels of minerals. The moisture content also increased gradually from 22.5% in C_{MT1} to 25.6% in C_{MT4} . This can be explained by the relatively high content of water in milk, which was used as an ingredient in the

formulations. It can be seen that the moisture content was relatively high for the developed formulations of sprouted black rice chocolate mousse, which suggests that they have a softer consistency and a shorter shelf life. In general, the formulations became progressively richer in protein, fat and fibre. Moreover, the increase in the content of these components was relatively significant, which suggests that the successive formulations were also richer in energy.

The content of carbohydrate in the developed chocolate mousse varied greatly from 47.9% in C_{MT1} to 50.4% in C_{MT4} . This can be explained by the relatively high content of this component in sprouted black rice slurry, dates and other ingredients used in the formulations. Carbohydrate is another energetically valuable component, providing 4 kcal per gram. The increase in the content of this component from C_{MT1} to C_{MT4} suggests that the successive formulations were richer in carbohydrate. The relatively high levels of carbohydrate, fat and protein in the developed sprouted black rice chocolate mousse indicated that the product could be caloric and energy-dense.

The corresponding energy values were 347 kcal for C_{MT1} , 465 kcal for C_{MT2} , 583 kcal for C_{MT3} and 692 kcal for C_{MT4} . It can be seen that the successive formulations were characterized by relatively high increases in the content of protein, fat, fibre, ash and carbohydrate. These changes affected the energy value, which was relatively high for all the investigated formulations of sprouted black rice chocolate mousse. It can be concluded that the developed product was a caloric food with a relatively high content of energy-providing components. It also contained significant levels of protein, fibre and minerals, which indicates its potential as a functional food. The product had a milk-like consistency with a chocolate taste, which could be of interest to the consumer.

Conclusion

The study concluded that sprouting enhanced the nutritional potential and functional applicability of black rice. The developed sprouted black rice flour contained 9.68% protein, 5.45% fibre, 6.30% ash and 66.60% carbohydrate, with an energy value of 338.06 kcal/100 g. Its incorporation into value-added products, including energy bar, chocolate, chocolate mousse and smoothie, progressively improved their nutritional composition. Increased levels of sprouted black rice generally enhanced protein, fibre, ash and carbohydrate contents. The findings demonstrate that sprouted black rice can serve as a promising functional ingredient for developing nutritious, energy-rich and value-added food products with potential for wider dietary utilization.

Table 1. Nutritional composition Sprouted black rice flour (in 100g):

The proximate analysis of the raw black rice flour is presented		
S. No.	Parameters	Test Result by %wt /Kcal
1	Protein	9.68
2	Fat	3.66
3	Fiber	5.45
4	Ash	6.3
5	Moisture	8.31
6	Carbohydrate	66.6
7	Energy	338.06

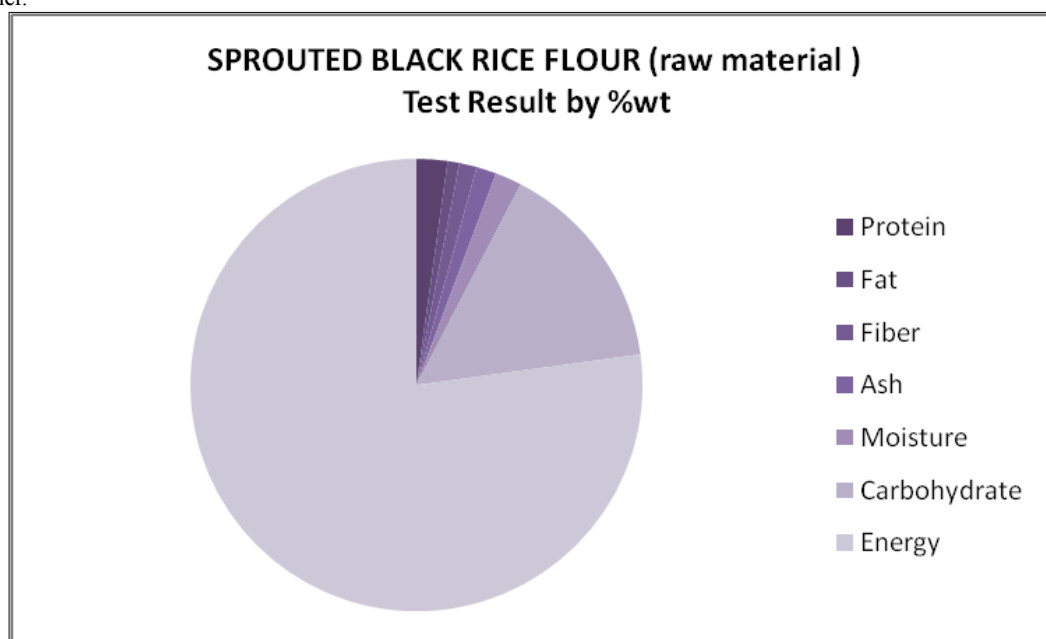


Table 2. Nutritional composition of control and value added Sprouted black rice Energy bar (in 100g):

SPROUTED BLACK RICE ENERGY BAR					
S. No.	Parameters	ET1 by %wt	ET2 by %wt	ET3 by %wt	ET4 by %wt
1	Protein	11.5	12.5	13.6	14.5
2	Fat	17.8	18.6	19.5	20.4
3	Fiber	7.2	8.5	9.5	10.6
4	Ash	3.1	4.2	5.6	6.4
5	Moisture	8.5	8.6	9.4	10.6
6	Carbohydrate	51.9	52.4	64.4	72.5
Energy					
S. No.	Parameters	ET1 Kcal	ET2 Kcal	ET3 Kcal	ET4 Kcal
1	Energy	414	531	635	763

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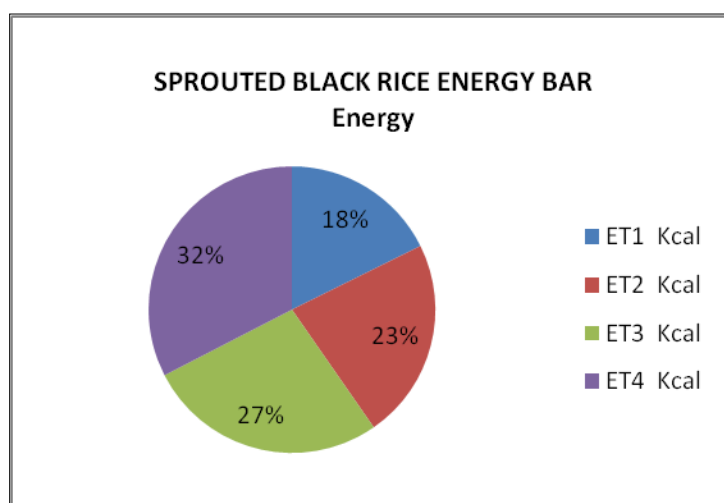
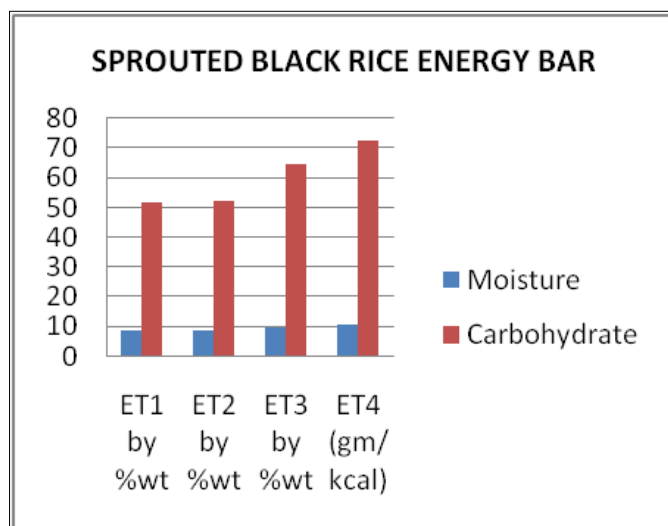
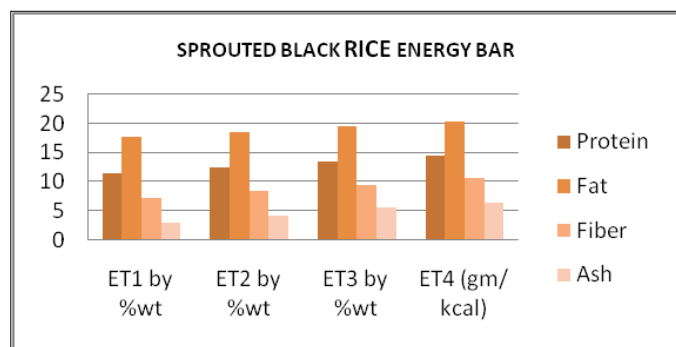
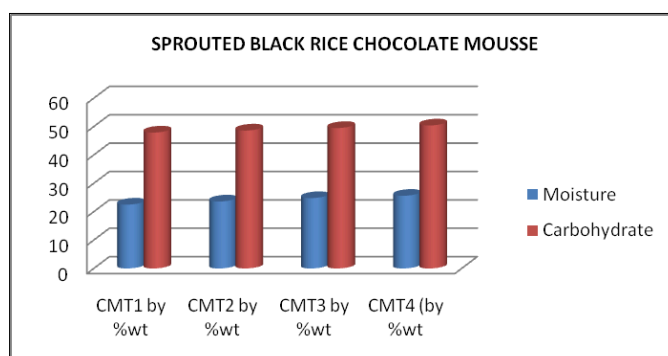
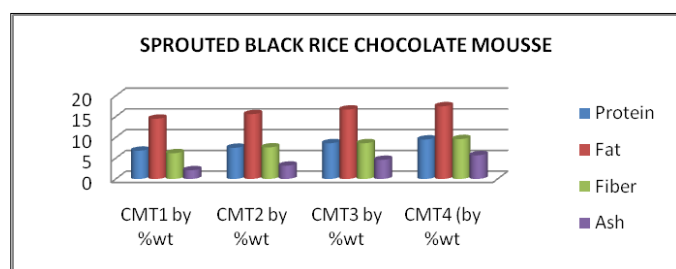
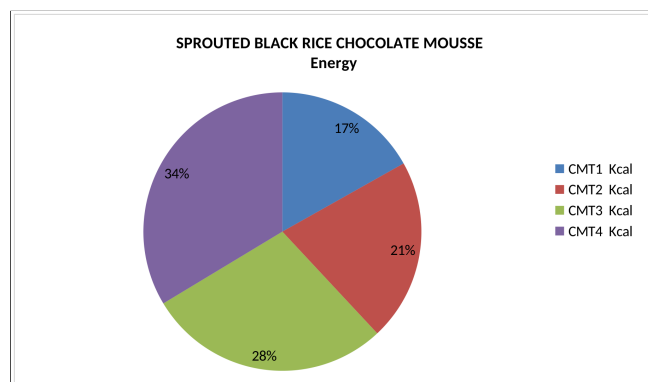


Table 3. Nutritional composition of control and value added Sprouted black rice chocolate mousse (in 100g):

SPROUTED BLACK RICE CHOCOLATE MOUSSE					
S. No.	Parameters	CMT1 by %wt	CMT2 by %wt	CMT3 by %wt	CMT4 by %wt
1	Protein	6.8	7.5	8.6	9.5
2	Fat	14.5	15.6	16.7	17.5
3	Fiber	6.2	7.6	8.6	9.6
4	Ash	2.1	3.2	4.6	5.7
5	Moisture	22.5	23.6	24.8	25.6
6	Carbohydrate	47.9	48.6	49.5	50.4
Energy					
S. No.	Parameters	CMT1 Kcal	CMT2 Kcal	CMT3 Kcal	CMT4 Kcal
1	Energy	347	436	583	692





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