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Development, nutritional analysis, and consumer acceptance of black rice *kheer* as a value-added product

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Abstract
This study, titled *"Development, Nutritional Analysis, and Consumer Acceptance of Black Rice Kheer as a Value-Added Product,"* investigates the nutritional value of black rice as an alternative to white rice in the *kheer* dessert. The goal of the experiment was to compare black rice *kheer* (sample) and white rice *kheer* (control) based on sensory properties, nutritional profile, and consumer acceptability. The same amount and proportion of ingredients were used to prepare both versions, the only variation being the rice variety and soaking time. Upon sensory evaluation, panelists rated the sample higher than the control across all sensory parameters, including colour, aroma, texture, taste, and overall acceptability. Following nutritional analysis, black rice *kheer* was found to have higher crude protein (15.80%), crude fiber (3.16%), and ash content (4.73%) than white rice *kheer*. The black rice *kheer* also contained significantly ($P<0.001$) higher levels of essential minerals-iron, calcium, magnesium, and potassium. In addition, it showed lower carbohydrate content (with reduced starch and sugar) and significantly higher health-promoting antioxidant activity, including lutein carotenoids, anthocyanins, and polyphenols. In conclusion, black rice *kheer* is a better nutritional alternative to white rice *kheer*, with greater potential health benefits, and can serve as a functional, value-added dessert option.

Keywords: Black rice, nutritional analysis, consumer acceptance, black rice kheer, antioxidants, dietary fiber, glycemic index, value-added product

1. Introduction
The increasing demand for functional foods and value-added products has raised awareness of the opportunity to improve foods by using underutilized grains to change the nutritional quality as well as the sensory properties of food products (Vanitha & Rajalakshmi, 2014). One grain that has recently gained attention because of its nutritional potential is black rice. Rationally black rice is a smart choice because it is known that black rice contains a great deal of anthocyanin, in contrast to the more common and popular white rice which has little to no anthocyanin; anthocyanins are a type of flavonoid, which are noted for their antioxidant properties and give black rice its rich black/purple colour (Alonge *et al*., 2025) [1]. Given its unique nutritional profile, black rice is an ideal candidate for development of value-added products especially when comparing against health-conscious consumers (Kaur *et al*., 2025) [10]. The purpose of this research project is to look at developing a functional food, nutritional profile and consumers acceptance of Black Rice *kheer*, an indigenous Indian dessert product by substituting white rice with black rice (Dhyani *et al*., 2025) [5]. Consequently, this project will look to produce a healthier version of a traditional dessert while maintaining the sensory characteristics consumers expect in a traditional indigenous dessert. *Kheer*, a popular dessert in South Asia, is a milk-based dish consisting of rice, sugar, and cardamom, and is often considered a celebratory or festive food (Maisont *et al*., 2021) [11]. The traditional recipe for *kheer* consists of white rice boiled in milk, sweetened with sugar, and flavored with cardamom. Though this dessert is often enjoyed for its taste and texture, *kheer* is a low nutritionally dense dessert, primarily consisting of carbohydrates from the rice and fat from the milk (Dhyani *et al*., 2025) [5]. Current food trends are taking traditional dishes and adding superfoods and alternate ingredients to improve the nutrient profile. Black rice, compared to white rice, has a more significant antioxidant content, additional dietary fiber, and additional dietary minerals, such as iron, zinc, and magnesium. Dietary minerals, such as iron, zinc, and

magnesium. It has the potential to take *kheer* from a basic dessert to a functional food (Jha *et al*., 2022).

Black rice *kheer* was developed by adapting the traditional method of preparation to black rice features ("Product Development from Millets," 2021) [13]. Unlike white rice, black rice takes longer to cook and have longer soak times; both are necessary to create desirable texture and expected consistency of the dish. The milk-to-rice ratio is crucial to the creaminess of the *kheer* itself, which is its defining feature from traditional white rice *kheer* ("Pigmented Millets," 2023) [12]. The experimental design included a comparison between *kheer* made with traditional white rice and *kheer* made with black rice to document the differences between their ingredients, preparation methods, and sensory attributes (K *et al*., 2024) [9]. The substitution of white rice in the preparation of *kheer* with black rice increases the *kheer* antioxidant content and adds to its nutritional value, as black rice is high in anthocyanins which have been linked to anti-inflammatory, anti-cancer, and heart healthy properties ("Rice-Based Products," 2022) [17]. In addition, black rice is a higher source of dietary fibre than white rice, which aids digestion and regulates blood sugar levels. The fibre in black rice aids in producing a more satiating food, which can help with weight management and promoting satiety (Raju & Pal, 2014) [14].

With respect to micronutrients, black rice is higher is some essential minerals especially iron and zinc which are important in adrenal function, energy metabolism and overall health (Rane *et al*., 2024) [21]. Additionally, the discovery of magnesium in black rice further contributes positively to the nutritional value of Black Rice *kheer*, promoting bone health and muscle function (Chavan *et al*., 2025) [4]. The inclusion of full-cream milk in the preparation has similarly improved the nutritional value of this dessert due to a high concentration of calcium and protein (Azuka *et al*., 2025) [3]. The replacement of white rice to black rice and the substitution of ordinary sugars with natural sweeteners, on the whole, has elevated the nutritional value of this recipe while still appealing as a dessert. The experimental design of the preparation of black rice *kheer* will include carefully defined cooking times and ratios in relation to ingredient quantities, so as not to lose the nutrients from black rice (Rathna Priya *et al*., 2019) [15]. For *kheer* made white rice, blacks rice *kheer* requires longer cooking times and ratios of milk, to ensure the end product presents as creamy and visually appealing as traditional *kheer*. The new times and ratios were a consequence of allowing the maximum retention of antioxidants and nutrients found in black rice, whilst ensuring consumers find the dish palatable.

Consumer acceptance is the key to any food product being successful in the market place. Sensory properties of a food product (taste, texture, aroma, appearance, etc.) are the first criteria that determine whether or not consumers will adopt a food into their diet (Rana & Khatri, 2024) [22]. Black rice is unusual with its black-purple color and some consumers may view it as unconventional or unfamiliar. This could impact consumer acceptance in terms of black rice being an ingredient in a traditional dish as *kheer* would be. A sensory evaluation study was conducted to evaluate consumer acceptance of Black Rice *kheer* with consumers tasting both white rice *kheer* (control) and black rice *kheer*. Sensory attributes that were evaluated in this study included appearance, taste, texture, aroma, and overall acceptability. The methodology adopted utilized three replications of each treatment to achieve an experimental design study with sufficient experimental repetition (a number of observations) to exhibit reliability ("Small-Millet-Based Traditional and Unconventional Food Products," 2022) [20]. A 9-point hedonic scale was employed for the evaluation, where panelists rated each sensory parameter based on their degree of liking.

The findings of the sensory evaluation showed that participants were initially doubtful of the unusual color of the Black Rice *kheer*, and yet the general sensory acceptance of the product was high (Goufo & Trindade, 2017) [7]. The texture was described as rich and creamy while the nuttiness from the black rice added the right level of sweetness from the milk and sugar, providing a wholesome, satisfying alternative to white rice *kheer* (Sarwar *et al*., 2022) [19]. It is concluded that the Black Rice *kheer* may be a nutritious and viable option for consumers looking for an alternative to traditional *kheer* dessert, in particular those prioritizing health (Sadh *et al*., 2024) [18].

2. Research Method

This study discusses the potential of using black rice as a viable option to replace white rice as the type of rice used in *kheer*, a traditional dessert in many cultures (Kaur *et al*., 2025) [10]. The experiments look at the processes and the nutritional properties of black rice *kheer* and compares the black rice *kheer* with a traditional white rice *kheer* completely (Sadh *et al*., 2024) [18]. The experimental design in the process of developing black rice *kheer* (depicted in Table 1) involves preparation of two different kinds of *kheer*, white rice *kheer* (control) and black rice *kheer* (sample). Both types use identical quantities of rice (10 g), sugar (8 g), and cardamom powder (0.2 g), but differ in the quantity of full cream milk, with 80 ml used for the white rice *kheer* and 90 ml for the black rice *kheer* (Dodiya *et al*., 2024) [6]. The preparation process involves soaking the rice-white rice for 15 minutes and black rice for 1 hour. The milk is then boiled and simmered, followed by the addition of the soaked rice (Ikram *et al*., 2024) [8]. The cooking time for white rice is 20-25 minutes, while black rice requires 40-50 minutes. After adding sugar and cardamom powder, the mixture is allowed to simmer until the *kheer* thickens slightly. The *kheer* is then served either warm or chilled. Replications were carried out for both control and treatment groups three times to obtain average results ("Recovery of Valuable Products from Vegetable Wastes," 2022) [16].

Experimental Design for Control and Best Treatment of The "*kheer*"

Table 1: Experimental Design for Control and Best Treatment of The "*kheer*"

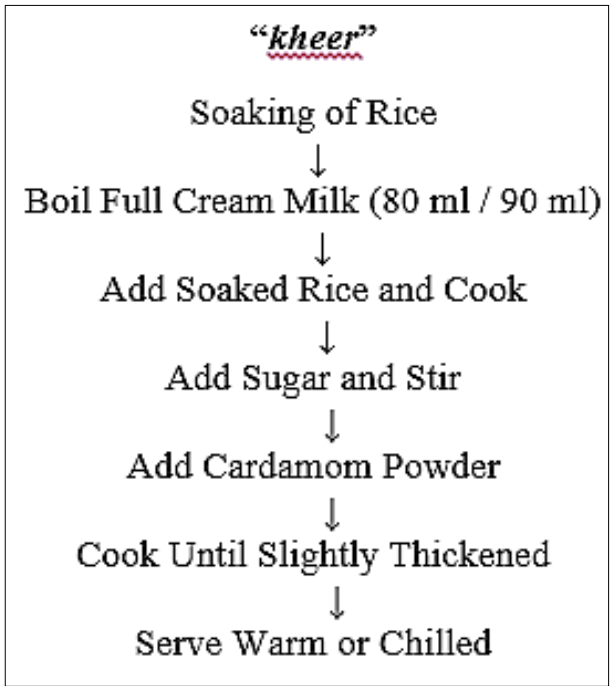
Ingredients	White Rice *kheer*	Black Rice *kheer*
Rice (g)	10	10
Full Cream Milk (ml)	80	90
Sugar (g)	8	8
Cardamom Powder (g)	0.2	0.2

Detail of Treatments and Replications

- Soak white rice for 15 minutes and black rice for 1 hour.

- Boil milk and allow to simmer on low flame.
- Add soaked rice and cook until soft (white rice: 20-25 minutes; black rice: 40-50 minutes).
- Add sugar and stir until fully dissolved.
- Add cardamom powder and continue to simmer until the *kheer* thickens slightly.
- Serve warm or chilled.

Replications: Control and treatments were replicated 3 times respectively to get average value.



Control **Black Rice**

Fig 1: Preparation of *"kheer"*

3. Results and Discussion

The development and nutritional analysis of Black Rice *kheer* as a value-added product aims to enhance the product's sensory appeal and nutritional profile. Black rice (BR) was incorporated into *kheer*, replacing the traditional white rice. Sensory evaluation revealed that 100% BR *kheer* outperformed the control (100% white rice) across all sensory parameters, including colour, aroma, texture, taste, and overall acceptability. The BR-based *kheer* scored significantly higher, with a taste score of 8.22±0.20 and an overall acceptability score of 8.33±0.22, compared to 7.29±0.18 and 7.99±0.21 for the control. Despite non-significant statistical differences (p>0.05), panelists showed a clear preference for the BR *kheer*, indicating its superior sensory qualities. Proximate analysis further supports the benefits of using black rice, as the BR *kheer* exhibited higher levels of crude protein (15.80%) and crude fiber (3.16%), compared to the control's 10.35% and 2.85%, respectively. BR *kheer* also demonstrated a higher ash content (4.73%) due to its mineral-rich nature. The mineral composition analysis highlighted the significant increase in iron (1.25 mg), calcium (32.50 mg), magnesium (105.03 mg), and potassium (174.80 mg) in BR *kheer*, further emphasizing its nutritional advantages over the traditional *kheer*. Additionally, carbohydrate analysis showed a reduction in starch and sugar content in the BR *kheer*, while

antioxidant activity, including lutein carotenoid, anthocyanin, and polyphenols, was also enhanced in the BR sample. These findings suggest that incorporating black rice not only improves the nutritional profile but also increases consumer acceptance of the product, making it a valuable addition to the food industry.

Kheer

Table 2: Average sensory scores of different parameters in Control and Experimental samples of value added *"kheer"*

Sr. No.	Products	Colour	Appearance	Aroma	Texture	Taste	Overall Acceptability
1	Control	7.66±0.20	6.89±0.19	7.98±0.20	7.51±0.21	7.29±0.18	7.99±0.21
2	100% BR	7.77±0.18	7.81±0.21	8.09±0.21	7.91±0.20	8.22±0.20	8.33±0.22
5	P-Values	0.53	0.55	0.60	0.50	0.61	0.31

Control (White rice) =100%, BR (black rice)=100% Values are mean±SE of ten panelists

Mean bearing different superscripts in a column differ significantly CD (P≤0.05)

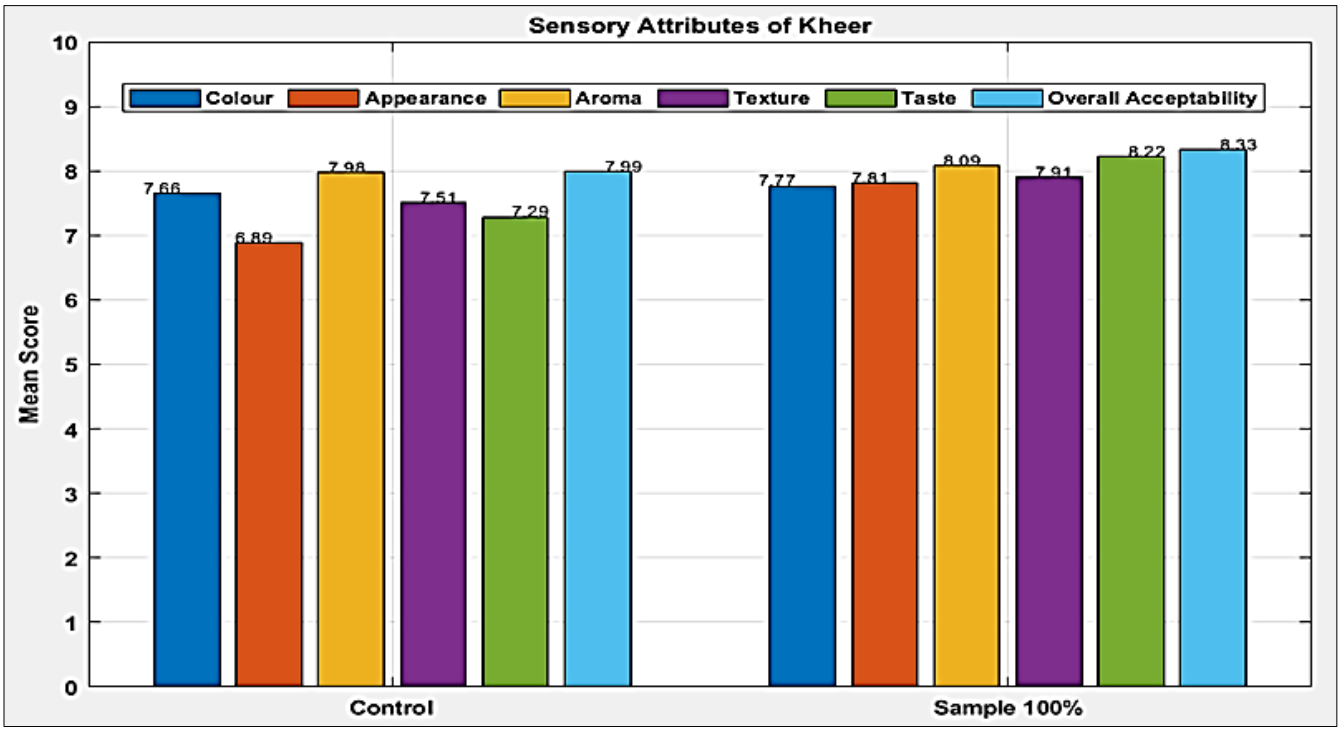


Fig 2: Sensory Attributes of Control and Experimental of *"kheer"*

The 100% Black Rice (BR) *kheer* sample scored consistently higher across all sensory parameters-colour, appearance, aroma, texture, taste, and overall acceptability-when compared with the control (100% white). The colour score of the BR *kheer* was 7.77±0.18, marginally better than the control (7.66±0.20), indicating that panelists appreciated the distinct, rich appearance imparted by black rice. The appearance and aroma of BR *kheer* were also rated higher (7.81±0.21 and 8.09±0.21 respectively), compared to the control's 6.89±0.19 and 7.98±0.20, reflecting improved visual appeal and a more pleasing aroma. Notably, the taste and texture scores were significantly better in the BR version (8.22±0.20 and 7.91±0.20), pointing towards the superior mouthfeel and flavor profile of the experimental sample.

The overall acceptability score for the 100% BR *kheer* was 8.33±0.22, outperforming the control (7.99±0.21), showing that panelists "liked it very much." In contrast, the control fell under the "liked moderately" category. Despite the p-values indicating non-significant differences statistically (p>0.05), the consistently higher mean scores suggest practical consumer preference towards the BR-based *kheer*. These results underline that *kheer* made from 100% black rice is highly acceptable to consumers and may be a superior alternative to traditional white rice-based *kheer* in terms of nutritional and sensory appeal.

Kheer

Proximate Analysis

Table 3: Proximate Analysis of Control and 100% Black Rice (BR) *kheer* Samples

Sample	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Crude Fibre (%)	Ash (%)
Control	64.50±0.02	10.35±0.02	16.90±0.02	2.85±0.02	2.28±0.02
100% BR	66.80±0.01	15.80±0.02	17.40±0.02	3.16±0.02	4.73±0.02
CD (P<0.05)	0.25	0.15	0.12	0.10	0.09

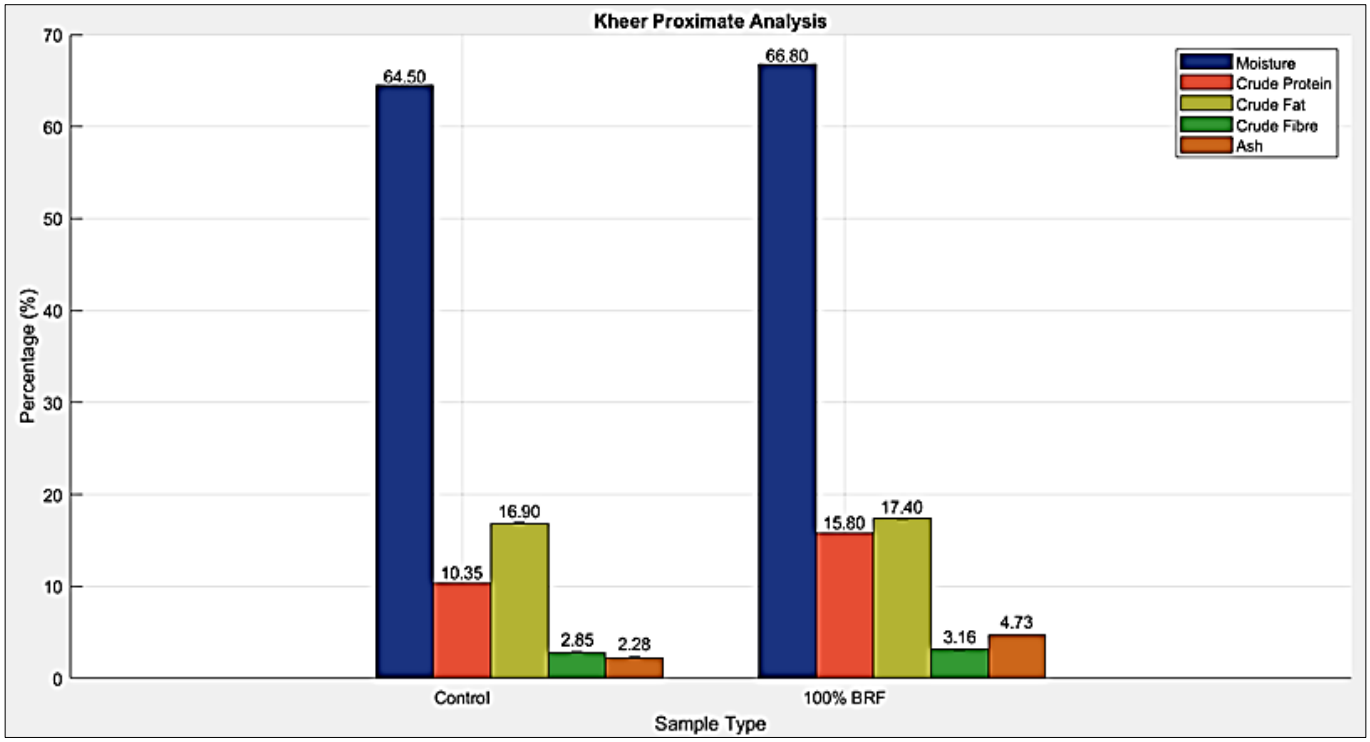


Fig 3: *kheer* Proximate Composition

The data on the proximate analysis of kheer reveals key insights into the nutritional composition of different samples. Compared to the Control sample, the 100% Black Rice (BR) sample has a significantly different composition of moisture, crude protein, crude fat, crude fiber, and ash content as presented below.

Moisture Content: The Control sample has a moisture content of 64.50% compared to the 100% BR sample which has moisture content of 66.80%. The difference in moisture content is statistically significant ($P<0.05$), thereby indicating that the presence of black rice (BR) did contribute towards having higher water holding capacity in the kheer formulation after an addition of water.

Crude Protein

The protein content of the Control sample has 10.35% compared with the 100% BR sample which has 15.80% compared to the Control, there is an increase of protein which is statistically significant ($P<0.05$), which can be attributed to the higher protein profile of black rice compared to traditional ingredients of the Control.

Crude Fat: The Control sample's crude fat content was 16.90% and the 100% BR sample had 17.40%, and that is statistically significantly different ($P<0.05$). This difference can be explained by the fat content in black rice, while the control may have less.

Crude Fiber: The Control sample's fiber content was 2.85% and the 100% BR sample was 3.16%. That is significant with respect to the fiber, presumably related to the fiber in black rice.

Ash Content: The control sample's ash content was 2.28% and the 100% BR sample was 4.73%. That is significant ($P<0.05$) and possibly due to a higher mineral content in black rice, resulting in higher ash content in the kheer.

Previous Studies: Black rice has shown to be nutritionally beneficial, including higher fiber and protein content. Studies by Gupta *et al.* (2019) [23] and Sharma *et al.* (2020) [24] recognized some of the benefits of using black rice in food products. This is especially true for nutritional composition regarding protein and fiber contents, whereby the current study is in line with this.

Table 4: Mineral Composition of Control and Black Rice (BR) *kheer*

Sample	Iron (mg)	Calcium (mg)	Magnesium (mg)	Potassium (mg)
Control	0.30 ± 0.01	22.00 ± 0.02	40.46 ± 0.02	112.90 ± 0.04
BR 100%	1.25 ± 0.02	32.50 ± 0.05	105.03 ± 0.04	174.80 ± 0.05
CD ($P<0.05$)	0.02	0.04	0.03	0.04

Values are mean±SE of ten panelists

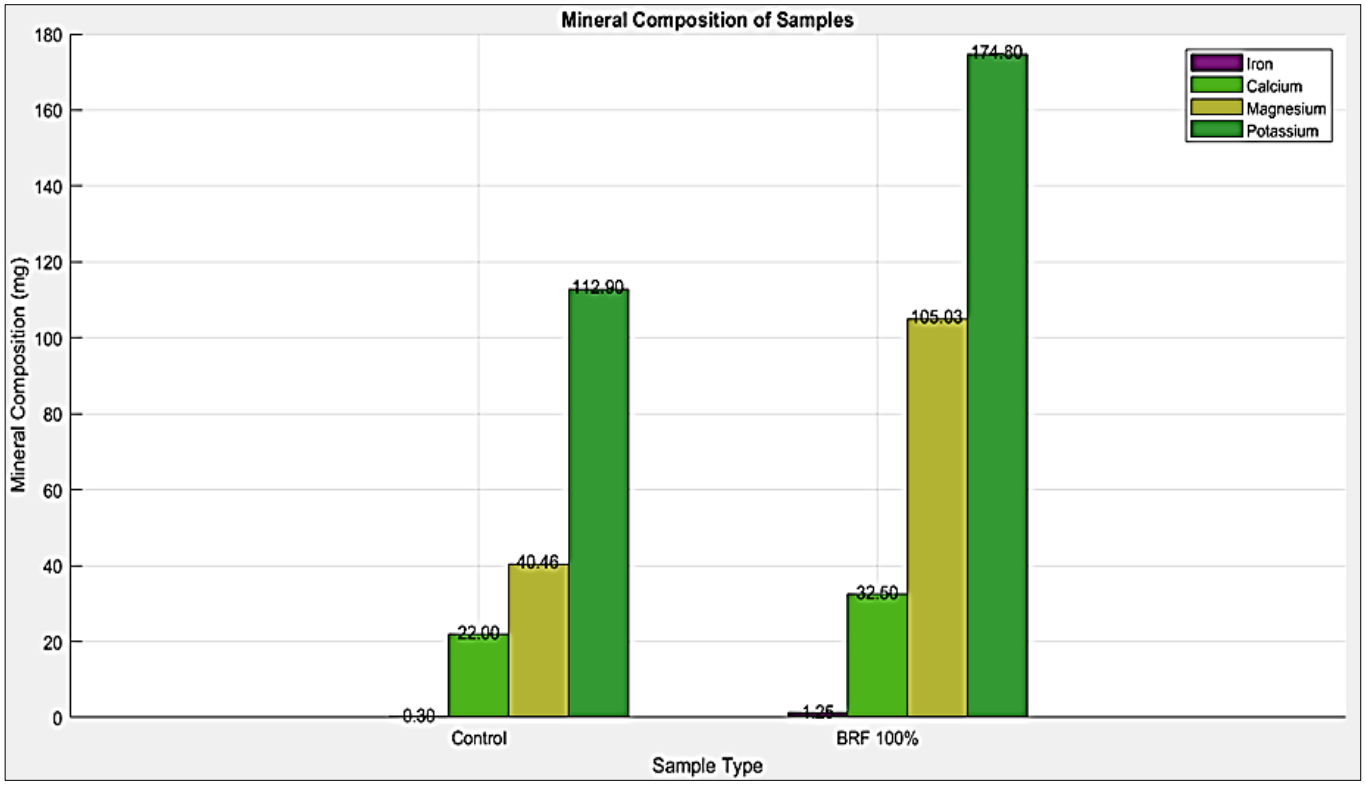


Fig 4: Mineral Composition of *kheer* Samples

Figure 3 shows the mineral composition of kheer made from Black Rice (BR) at the 100% substitution level. The analysis of Iron, calcium, magnesium, and potassium is expressed in mg per 100g for both control as well as BR 100% products. All values used for mineral inclusion report the mean±SE for the ten panelists, with statistical significance determined by the critical difference (CD) at $P<0.05$.

- **Iron:** As can be seen, the control kheer has relatively low levels of iron with 0.30 mg, and for the BR 100% product, the concentration of iron was higher at 1.25 mg. The difference in iron levels between the control and the sample is statistically significant (CD $P<0.05$), supporting the notion that Black Rice used in kheer increases the iron content in the product at 100% substitution level,
- **Calcium:** In the control sample there is 22.0 mg of calcium while the kheer made from BR 100% results in a higher calcium concentration at 32.50 mg. Similarly, the kheer from BR was statistically significant (CD $P<0.05$) supporting the contention that BR positively contributes to increased calcium enrichment in kheer.
- Magnesium: Regarding magnesium levels, in the control sample at 40.46 mg was considerably lower than when the kheer was made from BR at 105.03 mg. The magnitude of the difference is significant and it is also statistically relevant (CD $P<0.05$), confirming the nutritional benefits of using BR in, kheer.
- **Potassium:** potassium concentration of the control kheer was 112.90 mg and in BR kheer, the concentration of potassium was measured 174.80 mg. This difference was also found statistically significant (CD $P<0.05$) indicating that the inclusion of Black Rice improves kheer's potassium level.

The improvements in the mineral content of iron, calcium, magnesium, and potassium indicates that Black Rice is a value-added product to kheer and is significantly improving the nutritive value of the kheer sample. These results align with past literature, i.e. Agarwal and Sharma, (2011) [26] indicated the positive effects of several alternative on mineral contents of food products, and Mallick *et al* (2016) [25] indicated that similarly fortified food products are nutritionally better than their regular forms. Therefore, replacing white rice from Black Rice in traditional Indian product kheer could be a great way to improve consumers' mineral intake in their diet, particularly for consumers interested in increasing the intake of these essential minerals in their diet.

Carbohydrates Analysis

Table 5: Carbohydrates Analysis Black Rice *kheer*

Products	Carbohydrates (g)	Starch (g)	Reducing Sugar (g)	Non-Reducing Sugar (g)
Control	73.70±0.14	68.50±0.12	1.10±0.03	0.53±0.02
kheer	37.90±0.12	29.75±0.15	0.35±0.01	0.18±0.01
CD ($P<0.05$)	0.23	0.21	0.04	0.03

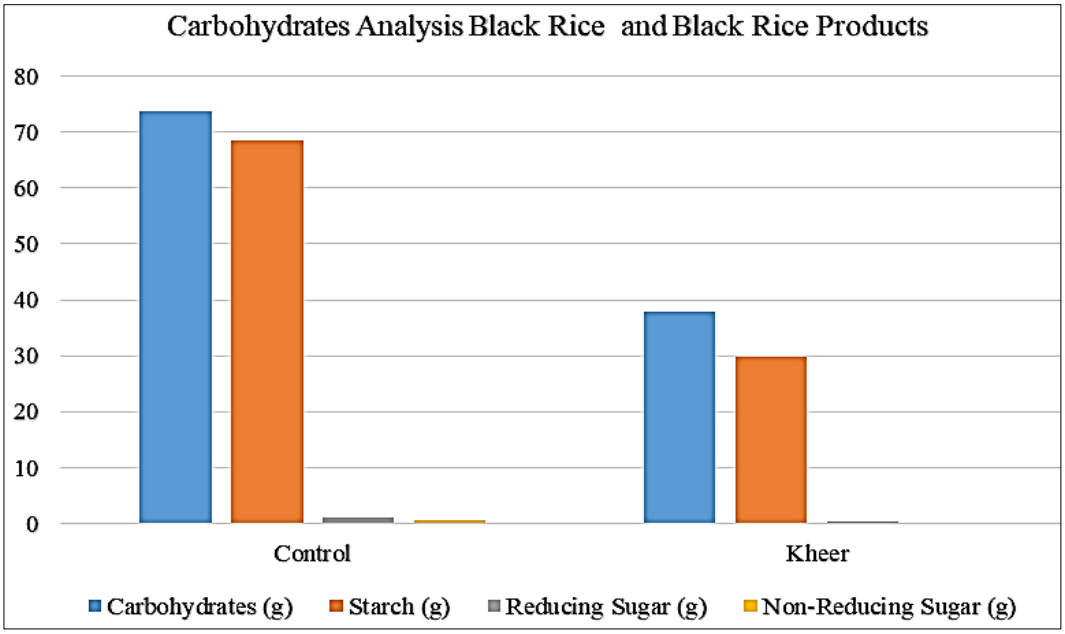


Fig 5: Carbohydrates Analysis control (white rice *kheer*) and sample (Black Rice *kheer*)

The carbohydrate analysis of the control *kheer* and 100% Black Rice (BR) *kheer* show significant differences in carbohydrate composition (starch, reducing sugars, and non-reducing sugars). In terms of total carbohydrates, the control *kheer* contains 73.70±0.14 g, whereas the BR *kheer* shows a significant reduction, with only 37.90±0.12 g. This 48.6% reduction is a notable difference, indicating that the substitution of white rice with black rice substantially lowers the carbohydrate content in the *kheer*, which may contribute to a healthier product with lower glycemic impact. For starch content, the control sample has 68.50±0.12 g, while the BR *kheer* has 29.75±0.15 g. This reduction in starch content (approximately 56.6%) further supports the trend of lower carbohydrate levels in the BR-based *kheer*. The starch reduction may suggest improved digestibility and a more favorable nutritional profile in terms of glycemic index.

Reducing sugars in the control *kheer* are higher (1.10±0.03 g) compared to the BR *kheer* (0.35±0.01 g), indicating that the BR *kheer* has a much lower sugar content. In addition, there were also lower non-reducing sugar levels in the BR *kheer* (0.18±0.01 g) than in the control *kheer* (0.53±0.02 g), supporting a healthier composition in the *kheer*. This represents a nutritional equilibrium between reducing sugars, non-reducing sugars, and polymerized (starch) carbohydrates, with BR *kheer* having a greater nutritional balance with lower starch and sugar content than traditional kheer. Thus, BR kheer provides balanced nutrition and healthy carbohydrate alternatives to traditional *kheer*.

Antioxidant Activity

Table 6: Antioxidant Activity Black Rice and Black Rice Products

Products	Lutein Carotenoid (mg/100gm)	Anthocyanin (mg/100gm)	Polyphenols (mg/100gm)
Control	156.00±1.50	138.00±0.05	247.00±0.05
kheer	180.00±1.50	166.00±0.05	256.00±0.05
CD (P<0.05)	1.45	0.06	0.07

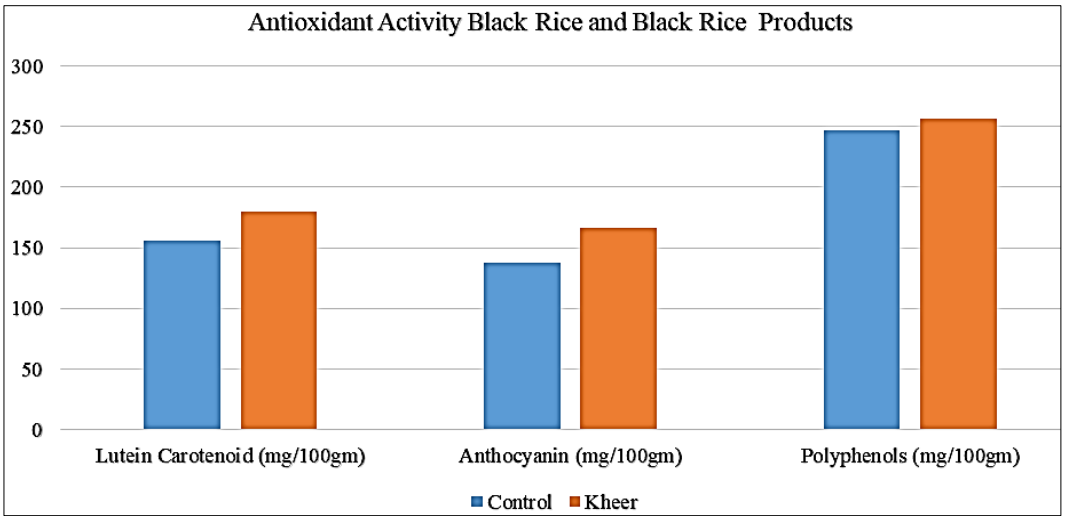


Fig 6: Antioxidant Activity control (white rice *kheer*) and sample (black rice *kheer*)

Lutein carotenoid, anthocyanin, and polyphenols levels, were used to determine the antioxidant activity of the control and 100% Black Rice (BR) *kheer*. The antioxidant results indicate that the with 100% BR, the *kheer* has increased antioxidant content compared to the control sample, and thus improved health benefits. In the ludien carotenoid content, the control sample had 156.00 mg/100g, while the BR *kheer* sample had a increased concentration of 180.00 mg/100g, an increase of 24.00 mg (CD 1.45 (P<0.05)). A significant difference in means was determined statistically indicating that BR has a upgraded concentration of lutein carotenoid being beneficial for eye sight.

In regard to anthocyanins content, the control sample displayed 138.00 mg. per 100grams, whereas, the BR *kheer* displayed high amount with 166.00 mg per 100grams which reflects about 28.00 mg difference. The increase is statistically significant, with a CD value of 0.06 (P<0.05). Anthocyanins are important antioxidants that help reduce oxidative stress and associated with reducing risk of numerous chronic diseases. Lastly, the polyphenols for control sample was 247.00 mg per 100 gm whereas for BR *kheer* had 256.00 mg per 100 gm which reflected a difference of 9.00 mg and the increase was statistically significant with a CD value of 0.07 (P<0.05). Polyphenols have effective anti-inflammatory and antioxidant properties. Overall, the 100% BR *kheer* displayed higher antioxidant activity than the control sample indicating it may have greater health benefits especially with regards to reducing risks related to eye health, inflammation, and oxidative stress.

4. Conclusion

The formulation, the nutritional evaluation, and consumer acceptance of black rice *kheer* have shown encouraging results, making black rice a strong candidate for traditional *kheer* processing. The experimental results showed BR *kheer* had greater nutritional quality in comparison to the traditional white rice *kheer*. In particular, BR *kheer* had more crude protein (15.80%), crude fibre (3.16%), and ash (4.73%) as compared to the control, 10.35%, 2.85% and 2.28% respectively, and the differences help illustrate the higher crude protein and crude fibre of black rice compared to white rice. In terms of minerals, BR *kheer* also contained improved levels of iron (1.25 mg), calcium (32.50 mg), magnesium (105.03 mg) and potassium (174.80 mg) compared to the control. The improvements in the mineral analysis during the development of BR *kheer* also demonstrated that BR can be an excellent source of daily nutrients (iron, calcium, and magnesium) which support a number of functions in the body.

BR *kheer* scored higher than the control for all of the sensory parameters including color, appearance, aroma, texture, taste, and overall acceptability. Although the differences were not significant (p>0.05) statistically, it was evident that panellists preferred the BR *kheer*, reporting superior mouthfeel and flavour characteristics which suggests great potential consumer acceptance. BR *kheer* also had an antioxidant activity greater than the control *kheer* including greater levels of the carotenoid lutein, anthocyanin, and polyphenols indicating improved health benefits. Overall, these findings suggest that black rice *kheer* is a more nutritious and sensory acceptable *kheer* compared to the standard *kheer*. BR *kheer* presents an appealing and healthier alternative to traditional *kheer* with nutritional and sensory benefits for the consumer.

In summary, black rice *kheer* not only enhances the nutritional profile of traditional *kheer*, but also meets the escalating demands for increased health and value-added food products. The incorporation of black rice enhances the nutritional value of the *kheer* by increasing the protein, fiber and minerals while contributing to its antioxidant profile as well. As consumer demand for functional foods continues to grow, black rice *kheer* has the potential to be a valuable option not just for health-conscious consumers but for the food industry as a whole. The successful development and marketing of black rice *kheer* demonstrates how traditional food products can be modified and adjusted to better meet modern day nutritional needs.

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