Evaluating the Nutritional Value and Physical Properties of White and Colored Rice and Their Application in Developing Some Food Products

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ABSTRACT

Rice (*Oryza sativa* L.) is a staple food for more than half of the world's population; however, excessive reliance on white rice, which lacks essential amino acids such as lysine, contributes to malnutrition, particularly among children. This study evaluated the effect of colored rice varieties (black and brown) on chemical composition and physical properties compared with white rice and assessed their application in selected food products to enhance nutritional value. Three rice varieties—Giza 177 (brown), Egyptian Yasmine (white), and black rice were analyzed for their physical, chemical, and cooking properties and incorporated into mahalabia and cake formulations at substitution levels of 2.5%, 5%, and 7.5%. Black rice showed the highest milling percentage (74%) and cooking time (22 min), while white rice had the greatest water uptake. Whole-grain types contained higher protein (8.25% and 7.75%) and fat (4.88% and 4.71%) contents than white rice (7.31% and 4.49%). Incorporating colored rice flour into food products altered moisture, fat, and protein levels: black rice increased moisture and fat, whereas brown rice enhanced fiber content. The use of colored rice flour improved the physical and sensory qualities of both mahalabia and cake.

Key word: Colored rice – Chemical composition-Physical properties.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for people in many countries and serves as the primary source of carbohydrates for more than half of the world's population. When the husk of paddy rice is removed, the grain obtained is called brown rice due to the brown color of the bran layer that covers the grain. White rice, on the other hand, is produced when this bran layer is removed during the regular milling process (Jiamyangyuen and Ooraikul, 2008).

Pigmented or colored rice varieties are distinguished by their brown, red, or dark purple covering layers. These pigments, located in the aleurone layer of the rice grain, are composed mainly of anthocyanin compounds, which belong to the flavonoid family, the phenolic compounds in colored rice are the major active components responsible for its antioxidant activity, with anthocyanins being the predominant phenolic substance (Zhang *et al.*, 2006 and Yawadio *et al.*, 2007).

Among colored rice types, black rice has received particular attention for its superior nutritional and functional properties. It contains higher levels of proteins, vitamins and minerals compared to common white rice (Kushwaha, 2016). Black rice is rich in essential amino acids such as lysine and tryptophan; vitamins including B_1, B_2, folic acid; and minerals such as selenium (Se), calcium (Ca), magnesium (Mg), phosphorus (P), zinc (Zn), potassium (K), and iron (Fe) (Baenziger *et al.*, 2009). It also contains the highest amount of antioxidants, protein, and dietary fiber among all rice varieties (Gani *et al.*, 2012). One serving of black rice (50 g) provides approximately (160) calories, (5 g) protein, (2 g) fiber, and (1 g) iron (Kang *et al.*, 2011).

Both brown rice and black rice provide valuable nutrients, vitamins, and dietary fiber; however, black rice is superior because it contains higher levels of protein, fiber, and antioxidants. Colored black rice contains up to six times more antioxidants than brown rice and has a higher content of phenolic compounds than other rice varieties (Das *et al.*, 2014).

Munarko *et al.* (2025) analyzed black, brown and red rice samples for proximate composition, pasting properties, texture and sensory attributes using the emotional sensory mapping (ESM) and rate-all-that-apply (RATA) methods. Significant differences were observed in moisture, ash, lipid, protein and carbohydrate contents among the samples. Kumar and Murali (2020) reported that black rice's dark color is due to anthocyanins present in the bran layer and that it is rich in tocopherols (vitamin E), iron and antioxidants. Bhardwaj (2021) further found that black rice bran contains high levels of anthocyanins, which contribute to its black-purple color and potent antioxidant activity.

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Moreover, Abd El-Raheam (2020) noted that rice milling quality, head rice yield, and degree of whitening were influenced by rice moisture content in Sakha 107 and Giza 177 varieties. Ejaz *et al.* (2020) evaluated the quality attributes of six rice cultivars in Pakistan and found differences in cooking and sensory qualities between brown and white rice, with consumer preference for white rice due to its color, aroma and texture.

Therefore, the present study aims to evaluate the nutritional value and physical properties of some types of colored rice and its use in preparing some food products to improve the nutritional value.

MATERIALS AND METHODS

A) Materials:

Three varieties of rice (*Oryza sativa* L.) namely Giza 177 (brown rice), white rice (Egyptian Yasmine) and Black rice were employed in this study. These samples were obtained from Rice Research and Training Center (RRTC) Sakha, Kafr El-Sheikh Governorate, Agricultural Research Center (ARC) Egypt during two seasons 2022 and 2023. All ingredients used for products were obtained from the local market of Alexandria Governorate.

B) Methods:

Raw rice samples were dehulled and then milled to obtain the white rice. The white rice was kept in polyethylene bags and stored at 4 °C until further analysis. All grains quality test (physical, milling and cooking characters) were conducted at Rice Technology Training Center, Laboratories Hager El-Nawatia, Alexandria Governorate, (ARC) while the chemical composition of rice grains and products were determined in Food Technology and Agronomy Laboratories of Faculty of Agriculture (Saba-Basha), Alexandria University and Rice Research and Training Center Laboratories, Sakha, Kafr El-Sheikh, (ARC), Egypt.

Preparation of cooked rice: Rice was thoroughly washed in a tap water at ambient temperature in order to remove any dust particles, present, drained and then cooked for 25 min as reported by Rewthong *et al.* (2011).

Preparation of Rice Flour: Rice flour was produced following the method described by Okpala and Egwu (2015).

Grain Quality characteristics: All the grain quality characters (length, width, shape) were measured according to Khush *et al.* (1979).

Determination of milling properties: Percentages (%) of hulling, milling, and head rice were estimated as reported by Roberts (1979).

Determination of cooking and eating quality: Kernel elongation ratio: Ten milled rice grains were measured using a Micrometer. The Grains were measured. Elongation ratio was calculated according to Azeez and Shafi (1966). Amylose content (%) was determined according to International Rice Research Institute (IRRI, 2009). Gel- Consistency (G.C.) was estimated, according to Cagampang *et al.* (1973). Gelatinization temperature (spreading and clearing) (G.t.) were determined according to Little *et al.* (1958).

Chemical composition of raw materials and products: ash, moisture, crude protein, ether extract and crude fiber contents of rice and wheat were determined according to the methods of the Association of Officiating Analytical Chemists (A.O.A.C., 2005). Ca, Mg, Fe, Zn, K, and P were determined according to the A.O.A.C. (2005) using an Atomic Absorption Spectrophotometer, Perkin Elmer (Model 3300, USA).

Functional properties of rice varieties: Water uptake at 75 ± 2 °C and 80 ± 2 °C, and cooking time of rice varieties were determined following the procedures of Simpson *et al.* (1965).

Cakes supplemented with different percent of black, brown and white rice flour: Wheat flour blended with 2.5, 5 and 7.5 % black, brown and white rice flour. Cakes were prepared according to Levent and Bilgiçli (2011).

Mahalabya supplemented with different percent of black, brown and white rice: The different samples of starch were blended with 2.5%, 5% and 7.5% from rice varieties. Mahalabya was prepared according to Kristanti and Herminiati (2019).

Statistical analysis: All the analytical data were carried out at least in triplicate and expressed as mean ± standard deviation (SD). Data were statistically analyzed by analysis of variance ANOVA and significant differences were identified by Duncan's Multiple Range test (p <0.05) (Steel and Torrie, 1980).

Results and Discussions

Table (1) presented the mean values for grain shape traits of different rice varieties. The mean values indicated that grain shape traits varied significantly among rice varieties, reflecting underlying genetic differences. A very key trait was length, with 7.12 mm values were significantly different in performance in the black and brown, which were 5.37 mm and 5.37 mm, respectively. Means differences in the trait of the shape factor, white, big high the performance was better than rice. However to rates related to trait's the rates black grains were means significantly and brown less for width if see to mean values was very by values 3.84 mm, were biggest of grains black and also performance as compare in the grains, rice in different 1.99 mm as compared the group traits and traits shape white and grains, grains length shape traits values 1.39, which thickness to important for thickness to rice white. For analysis value with the traits thickness brown were higher grains and big and other rice, for number level showed significantly that shape traits white the performance quality.

Table (2) presented the mean values for milling traits of different rice varieties: hulling, milling, and head rice (%). The LSD values were provided to facilitate statistical comparisons between variety means ($p < 0.05$).

The results indicated that there were no significant differences in hulling (%) among the varieties tested (around 75.00 -78.00%), suggesting limited genetic variability for this trait within this varieties. However, black rice exhibited a significantly higher milling (%) (74.00%) compared to brown rice (63.33%) and white rice (61.00%). This results suggested that black rice varieties possess a genetic advantage for overall milling yield. Brown rice had the highest head rice (%) (60.00%), while white and black rice had a significant reduction in this important milling trait (57.33% and 53.00%, respectively).

These results agreed with Febina *et al.* (2023) who studied five popular and traditional rice samples (Rakthashali, Pokkali, Kuruva, Matta and Jaya) as milled which collected from Rice Research Station, Angamaly, Kerala, India. The results showed that the longest grain length was recorded for Jaya and Pokkali (7 mm), followed by Matta (6 mm), Rakthasali (5 mm) and Kuruva (4 mm). The grain width ranged between 2 and 3 mm, with no statistical significance.

Qadeer (2025) evaluated the physical properties of rice samples from two distinct varieties, GQTL 1401 (01 and 02 Sample), collected from the National Agricultural Research Center, Islamabad. The length of sample 01 had a higher length (7.675 mm) compared to sample 02 (7.44 mm) followed by breadth of sample 02 showed a higher breadth (1.74 mm) compared to sample 01 (1.686 mm) and thickness of sample 01 had a thickness of 4.48 mm, while sample 02 had a slightly higher thickness of 4.484 mm. The length/breadth (L/B) ratio and quality index values indicate the overall size and quality of the grains, with sample 01 having slightly higher values compared to sample 02.

Table (3) showed that white rice exhibited the highest water uptake (291 ml), which were significantly greater than that of brown rice (285 ml), which in turn were significantly higher than black rice (270 ml). This variation is directly attributable to the physical structure of the rice kernel and the presence of the bran layer. White rice, a polished grain consisting almost entirely of the starchy endosperm, allows for rapid and unimpeded hydration. In contrast, the bran layers of brown and black rice act as a physical barrier. This layer is rich in fibrous, water-insoluble components and lipids, which are hydrophobic, collectively slowing the rate of water penetration into the kernel's interior. The data suggest that the bran layer of black rice presents a more formidable barrier to hydration than that of brown rice, resulting in the lowest water uptake (Zhang *et al.*, 2022).

The Cooking time results presented a clear and logical consequence of these differences in hydration. Black rice required the longest cooking time at 22.0 minutes, which was significantly longer than the other two varieties. This prolonged cooking duration is a direct result of its slow water uptake (Abouel-Yazeed *et al.*, 2019).

Table 1. The mean squares for grain shape traits of rice varieties

Rice varieties	Grain length (mm)	Grain width (mm)	Grain shape	Grain thickness (mm)
Black rice	$5.37^{b} \pm 0.03$	$3.16^{b} \pm 0.11$	$1.78^{b} \pm 0.16$	$1.99^{b} \pm 0.07$
Brown rice	$5.37^{b} \pm 0.23$	$3.84^{a} \pm 0.08$	$1.39^{c} \pm 0.09$	$2.79^{a} \pm 0.12$
White rice	$7.12^{a} \pm 0.09$	$2.25^{c} \pm 0.16$	$3.17^{a} \pm 0.07$	$1.67^{c} \pm 0.05$
LSD (0.05)	0.223	0.34	0.106	0.147

^{abc} Means in the same row with different letters were significantly different at $p < 0.05$.

Table 2. The mean values for milling traits of different rice varieties

Rice varieties	Hulling (%)	Milling (%)	Head rice (%)
Black rice	$77.67^{a} \pm 0.33$	$74.00^{a} \pm 0.41$	$53.00^{c} \pm 0.18$
Brown rice	$78.00^{a} \pm 0.50$	$63.33^{b} \pm 0.23$	$60.00^{a} \pm 0.32$
White rice	$75.00^{a} \pm 0.63$	$61.00^{b} \pm 0.44$	$57.33^{b} \pm 0.09$
LSD (0.05)	6.65	5.60	2.20

^{abc} Means in the same row with different letters were significantly different at $p < 0.05$.

The tough, intact bran layer, which includes the colored pericarp unique to black rice, significantly slows both water penetration and heat transfer to the starchy endosperm. More time is therefore required to achieve the complete gelatinization of starch granules, which defines the point of being fully cooked. Interestingly, while brown rice had the numerically shortest cooking time (19.0 minutes), it was not statistically different from white rice (19.8 minutes), as indicated by their shared letter 'b'. This suggests that while the brown rice bran layer does slow hydration compared to white rice, its effect on the overall cooking time was not significant in this experiment.

In conclusion, the data demonstrates a strong and predictable relationship between the physical structure of the rice grain and its cooking characteristics. A clear inverse relationship is evident: the varieties with more intact and complex bran layers (black > brown > white) exhibited progressively lower rates of water uptake, which in turn led to significantly longer cooking times, particularly for black rice. These findings have direct practical implications for consumers and food processors, as they quantify the "cooking penalty" associated with the nutritional benefits of whole-grain rice varieties. The structural integrity of the bran layer is therefore the primary determinant of these key cooking properties, dictating both the amount of water absorbed and the time and energy required for preparation (Zhang *et al.*, 2022).

Table (4) presented the mean values for grain elongation, gelatinization temperature, and amylose content in different rice varieties. The LSD values were provided to facilitate statistical comparisons between variety means (p <0.05). Brown rice (44.90 mm) and white rice (42.13 mm) exhibited significantly higher grain elongation compared to black rice (26.37 mm). This demonstrated a significant difference in a key cooking quality trait, with implications for the final texture and appearance of the cooked rice. These results suggested that consumers seeking rice with high grain elongation after cooking would likely prefer brown or white rice varieties over black rice. There were also significant differences found in gelatinization temperature. Brown rice (6.00 °C) had a significantly higher gelatinization temperature than white rice (5.00 °C). This indicated that brown rice may require longer cooking times compared to white rice to achieve optimal gelatinization, a factor that could influence consumer preference and cooking practices. Black rice (5.67 °C) showed an intermediate value, not significantly different from either brown or white rice.

No significant differences were observed among the rice varieties for amylose content. This suggested that amylose content, a key determinant of cooked rice texture, was relatively uniform across the tested varieties or that a larger sample size or more precise measurement techniques would be required to detect significant differences.

Amylose content varied among At-306, At-309 and At-405 Basmati-type rice varieties. At-306, At-309 and At-405 were found to be high, intermediate and low amylose varieties, respectively. The high amylose rice showed intermediate gelatinization temperature and the highest values of cooking time, water uptake ratio, and solid gruel loss compared to that of low-amylose rice. The soaking water absorption rate into the rough rice grains exponentially increased with time and temperature.

Table 3. Water uptake and cooking time of rice varieties

Rice varieties	Water uptake (ml H_2O/100 gm. Rice) 80±2 °C	Cooking time (min)
Black rice	270^{c} ± 0.45	22.0^{a} ± 0.25
Brown rice	285^{b} ± 0.68	19.0^{b} ± 0.57
White rice	291^{a} ±0.55	19.8^{b} ± 0.44
LSD (0.05)	5.68	1.2

[abc] Means within a column by the same letters are not significant.

Table 4. The mean values for grain elongation, gelatinization temperature, and amylose content in different rice varieties

Rice varieties	Grain elongation (mm)	Gelatinization temperature (°C)	Amylose content (%)
Black rice	26.37^{b} ±0.14	5.67^{ab} ±0.15	16.83^{a} ±0.22
Brown rice	44.90^{a} ±0.30	6.00^{a} ±0.06	18.00^{a} ±0.07
White rice	42.13^{a} ±0.07	5.00^{b} ±0.11	17.90^{a} ±0.12
LSD (0.05)	6.689	0.756	1.632

[ab] Means in the same row with different letters were significantly different at p < 0.05.

The differences in soaking water absorption of three varieties varied according to their amylose contents. The Peleg's soaking water absorption kinetics showed that the low amylose Basmati-type rice would get hydrated faster with increasing temperature than high amylose rice, implying comparatively less energy consumption during hot water soaking (Bandara *et al.*, 2025).

Qadeer (2025) evaluated the cooking properties of rice samples from two distinct varieties, GQTL 1401 (01 and 02 Samples). The alkali spreading test indicated that sample 01 had a higher alkali spreading value (Score 01), corresponding to a low gelatinization temperature. In contrast, sample 02 had a lower alkali spreading score (Score 06), indicating a higher gelatinization temperature. Sample 01 amylose content ranged from 20.32% to 21.77% and sample 02 amylose content ranged from 13.13% to 17.95%. Moreover, sample 01 showed a significantly higher amylose content than Sample 02, indicating a more firm and less sticky cooked rice. Gel consistency tests showed that both rice varieties exhibited soft gel consistency, as evidenced by gel lengths exceeding 70 mm. This soft gel consistency is typically associated with lower amylose content, which is consistent with the findings for sample 02.

Table (5) presented comprehensive chemical analysis of different rice varieties (black, brown and white). The analysis of the major macronutrients reveals a pattern directly linked to the bran layer. White rice, which is purely endosperm, exhibited the highest Fiber content (4.88%), a result that is counterintuitive as bran is the primary source of fiber. This suggests that the fiber measured in the white rice may be predominantly of a different type (e.g., resistant starch) or that the analytical method used captured non-bran components, which warrants further investigation. Conversely, the whole-grain varieties, black and brown rice, had significantly higher protein (8.25% and 7.75%, respectively) and Fat (4.88% and 4.71%) content compared to white rice (7.31% and 4.49% for protein and fat, respectively). This is physiologically consistent, as the bran and germ layers, which are retained in whole grains, are known to be rich depositories of protein, lipids, vitamins, and minerals. The highest Ash content, an indicator of total mineral content, was found in white rice (3.33%), which again is an unexpected result that may be linked to the specific mineral composition of the endosperm versus the bran.

The results of this study agreed Ravikumar and Thomas (2023) who compared the compositional analysis of four varieties of rice-Cheruvally, Njavara, D1 and Bhadra. The results indicated that the percentage of moisture content ranged from 4.6-11.94% with D1 variety bearing highest value and Njavara with lowest. The ash content of the rice cultivars was in the range of 0.75 to 1.45% and ash content creates an insight of the element of minerals available in the food product. The lipid content was high for Bhadra (2.4%) followed by Njavara (1.8%), Cheruvally (1.61%) and least for D1 (1.58%). Maximum stability of food product can only be guaranteed for low fat foods. Crude protein analysis was also conducted and recorded results ranged from 7.93 to 12.56%. Results of carbohydrate content falls within the range of 73.49 to 81%, with Njavara being the highest one. Three individual samples of rice (red, brown, and black) were analyzed for proximate composition, the rice sample differed in their physicochemical properties, with moisture, ash, lipid, protein, carbohydrate, total energy, and energy from lipids ranging from 10.72–12.56 g/100 g, 2.88–3.57 g/100 g, 5.48–6.69 g/100g, 9.66–12.06, 67.03–69.73 g/100 g, 365.7–376.3 kcal/100 g, and 49.3–60.2 kcal/100g, respectively (Munarko *el al.*, 2025).

Table (6) showed the mineral content of different rice varieties (black, brown and white). Black rice demonstrated a significantly higher accumulation of Ca (0.76±0.03 mg), Zn (36.33±2.51 mg) and Fe (3.28±0.02 mg) compared to brown rice and white rice. This preferential accumulation suggested a unique genetic mechanism in black rice varieties that enhances the uptake and translocation of these micronutrients. Given the widespread prevalence of Ca and Zn deficiencies in human populations, these findings highlight the potential of black rice as a valuable dietary source and a target for bio-fortification efforts.

Table 5. Chemical composition of different rice varieties (mean ±SD)

Rice varieties	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
Black Rice	9.73^{a}±0.02	4.88^{a}±0.06	8.25^{a}±0.07	2.48^{c}±0.08	3.17^{b}±0.07	67.03^{a}±0.05
Brown Rice	9.41^{b}±0.13	4.71^{a}±0.08	7.75^{b}±0.05	2.70^{b}±0.05	2.70^{c}±0.05	63.36^{b}±0.02
White Rice	9.63^{a}±0.08	4.49^{a}±0.15	7.31^{c}±0.16	4.88^{a}±0.04	3.33^{a}±0.02	66.22^{a}±0.01
LSD (0.05)	0.154	1.283	0.146	0.115	0.073	0.642

[abc] Means in the same row with different letters were significantly different at $p < 0.05$.

Table 6. The mineral content of different rice varieties (black, brown and white) (mean ±SD)

Rice varieties	Ca (mg)	Zn (mg)	Fe (mg)	K (mg)	P (mg)
Black rice	0.76^{a}±0.03	36.33^{a}±2.51	3.28^{a} ±0.02	0.26^{b}± 0.01	0.18^{b}±0.01
Brown rice	0.09^{b}±0.01	28.00^{b}±2.00	2.90^{b}± 0.02	0.32^{a}±0.01	0.26^{a}±0.01
White rice	0.07^{b}±0.01	25.33^{b}±0.58	1.21^{c}±0.03	0.29^{ab}±0.01	0.19^{b}±0.01
LSD (0.05)	0.032	3.92	0.046	0.029	0.015

[abc] Means in the same row with different letters were significantly different at $p < 0.05$.

Black rice, conversely, exhibited the highest Fe content (3.28±0.02 mg). While this is a nutritionally positive trait, it is essential to consider the bioavailability of Fe in different rice varieties. This was in contrast to White rice that had significantly least level of Fe (1.21±0.03 mg). Brown rice showed a significantly higher K content (0.32±0.01 mg) compared to the control and black rice, underscoring its role as a good source of this essential electrolyte. The relatively low K content in black rice (0.26±0.01 mg), despite its high Ca and Zn levels, suggested that different genetic pathways may regulate the accumulation of these minerals. Brown rice varieties, high significantly in P traits, suggested to better and this good for health benefit for consumer; while Black rice had low this value for in this minerals.

Thomas *et al.* (2015) found that minerals such as Ca and Fe were high in black rice (21.38 mg/100g) and brown rice (0.81 mg/100 g). The dominant macro-mineral detected was Mg and K content was found to be high in black rice (K, 186.54 mg/100 g and Mg, 107.21 mg/100 g) and brown rice varieties (K, 197.41 mg/100 g and Mg, 95.09 mg/100 g). Further, the essential micronutrients such as Mg and Zn were found in appreciable amounts in brown rice (1.93 mg/100 g) and black rice (0.29) varieties, respectively.

Kumar and Murali (2020) reported that black rice has high levels of minerals (Fe, Zn, Ca, P and Se) compared to that of white rice.

Table (7) presented the chemical composition of Mahalabia. The control Mahalabia (varieties 1) exhibited a moisture content of 8.42 ± 0.13%, representing the baseline moisture level without rice flour addition. The protein content in the control was the highest among all varieties, at 11.79 ± 0.09%, which were significantly higher than all other varieties, indicating a dilution effect on protein concentration with rice flour incorporation. The ash content was moderate at 0.56 ± 0.04%, which was in the middle values of all varieties. Rice varieties with black rice (rice varieties 2, 3 and 4) showed a marked increase in moisture content, with rice varieties 2 (2.5% black rice) exhibiting the highest moisture (10.01 ± 0.03%), significantly greater than the control and other rice varieties ($p < 0.05$). The fat content was highest in this group, with rice varieties 2 had the highest value, 6.35 ± 2.34%, while rice varieties 3 and 4 showed the lowest protein and fiber. Brown rice varieties (rice varieties 5, 6 and 7) also showed high moisture contents, with values ranging from 9.41 ± 0.12% to 9.93 ± 0.07%.

Table 7. Chemical composition of Mahalabia (mean ±SD)

Rice varieties	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
Control	8.42^{g} ±0.13	6.06^{ab}±0.19	11.79^{a} ±0.09	0.59 ±0.05	0.56^{b} ±0.04	65.27^{c} ±0.49
black rice 2.5	10.01^{a} ±0.03	6.35^{a} ±2.34	7.19^{bd} ±0.06	0.37^{e}±0.07	0.44^{c} ±0.05	66.00^{a} ±0.10
Black Rice 5	9.32^{e} ±0.076	4.95^{bc}±0.41	7.16^{cd} ±0.02	0.38^{de}±0.03	0.49^{c} ±0.04	65.91^{ab} ±0.19
Black Rice 7.5	8.93^{f} ±0.02	4.78^{b}±0.08	7.22^{bed}±0.08	0.65^{c} ±0.17	0.68^{a}±0.08	65.81^{ab} ±0.42
Brown Rice 2.5	9.93^{ab}±0.07	4.79^{bc}±0.06	7.26^{bc} ±0.07	0.79^{b}±0.04	0.51^{bc}±0.03	66.18^{a} ±0.17
Brown Rice 5	9.71^{cd} ±0.06	4.75^{b} ±0.05	7.23^{bd} ±0.06	0.94^{a}±0.08	0.50^{bc}±0.50	65.91^{ab} ±0.28
Brown Rice 7.5	9.41^{e} ±0.12	4.71^{b} ±0.07	7.24^{bd} ±0.10	0.95^{a}±0.05	0.32^{d}±0.03	65.33^{b} ±0.84
White Rice 2.5	10.03^{a} ±0.15	4.64^{b}±0.07	7.10^{d} ±0.09	0.37^{de}±0.08	0.35^{d}±0.05	66.52^{a} ±0.20
White Rice 5	9.85^{be} ±0.05	4.55^{c} ±0.05	7.19^{bd} ±0.03	0.60^{c}±0.05	0.36^{d}±0.03	66.36^{a} ±0.15
WhiteRice 7.5	9.63^{d} ±0.08	4.49^{b}±0.15	7.31^{b} ±0.16	0.48^{d}±0.04	0.33^{d}±0.03	66.22^{a} ±0.01
LSD (0.05)	0.154	1.283	0.146	0.115	0.073	0.642

[abcdefg] Means in the same row with different letters were significantly different at $p < 0.05$.

The fiber content increased with brown rice flour concentration, with rice varieties 6 and 7 (5% and 7.5% brown rice, respectively) showing the highest fiber levels (0.94 ± 0.08% and 0.95 ± 0.01%, respectively), significantly different from the control (0.59±0.05%) and other rice varieties, indicating fiber enrichment with brown rice. The ash content, however, decreased with the incorporation of 7.5% of Brown rice (0.32 ± 0.03%). White rice varieties (rice varieties 8, 9 and 10) exhibited moisture contents comparable to the brown rice varieties.

Our results was agree with Achimugu *et al.* (2021) who showed that the proximate qualities of custard powder produced from selected cereals (guinea corn, maize, rice and millet) ranged between 9.95-14.05% for moisture, 1.20-2.78% for ash, 1.10-2.31% for crude fiber, 4.75-5.50% for fat, 7.96-12.88% for protein and 66.49-70.58% for carbohydrate content.

Table (8) presented chemical composition of cake samples made with different rice varieties. The control cake (Rice varieties 1) showed a moderate moisture content of 12.24 ± 0.29%, but the control cake was significantly lower in moisture content than all rice flour rice varieties. It had a high fat content of 17.42 ± 0.18%. The control cake contained the highest protein (11.69 ± 0.08%), high fiber (4.38 ± 0.11%), and high ash (4.81 ± 0.26%). The high values in control showed that ingredients significantly impacted protein, fiber and ash. Rice varieties with black rice (rice varieties 2, 3 and 4) had significantly higher moisture content than the control, with rice varieties 2 (2.5% black rice) showing the highest moisture at 18.04 ± 0.48%. Fat content was also elevated in the black rice varieties, with rice varieties 3 (5% black rice) exhibiting the highest fat content (19.52 ± 0.10%). The protein content decreased with black rice flour content (from 10.17 to 9.89% from levels 2.5 to 7.5%). There were low Ash and fiber. This suggested that black rice flour contributed to increased moisture and fat levels in the cake, while decreasing other nutritional characteristics.

White rice varieties (rice varieties 8, 9 and 10) exhibited moisture contents comparable to the brown rice varieties. White rice had the highest fiber content.

The brown rice varieties (rice varieties 5, 6 and 7) showed high moisture contents similar to black rice varieties (between 17 and 18%). The fat content was lower with brown rice incorporation, with the lowest fat at 14.72 ± 0.07% at a 2.5% level. The highest levels of fiber are in group 5 at all levels. This may have sensory impacts with high fiber. White rice varieties (rice varieties 8, 9 and 10) exhibited moisture contents comparable to the black and brown rice varieties. The fat contents showed the same trend as with all rice types of flour. There was a decreasing trend for Protein fiber.

Gogoi *et al.* (2025) showed that black rice had higher nutrient content, being a richer source of protein, Fe, Mg, vitamins B_2, B_3, B_6, total carotenoids, lutein, tocopherol and available carbohydrates compared to red rice, while red rice showed high dietary fiber, resistant starch, tocotrienols and amylose content. Further, a recommended dietary allowance (RDA) highlighted that black rice meets comparatively higher nutritional requirements than red rice; intake of 300 g suffices RDA of protein between 42.0–67.5% (black rice) and 39.3–52.5% (red rice) for a sedentary adult. Similarly, black rice met 44.1–69.9% of the RDA for fat and 52.2–118.0% for dietary fiber, while red rice provided 40.2–63.3% (fat) and 30.6–113.0% (dietary fiber).

Table 8. Chemical composition of cake (mean ±SD)

Rice varieties	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
Control Cake	12.24^{d} ±0.29	17.42^{c}±0.18	11.69^{a} ±0.08	4.38^{b} ±0.11	4.81^{a} ±0.26	52.80^{d} ±0.27
black rice 2.5	18.04^{ab} ±0.48	18.73^{b}±0.15	10.17^{bc} ±0.14	5.91^{a} ±0.02	3.14^{b} ±0.07	59.22^{a} ±0.25
Black Rice 5	17.62^{c} ±0.23	19.52^{a} ±0.10	10.31^{b} ±0.09	5.86^{ab} ±0.06	3.10^{bc} ±0.04	58.01^{ab} ±0.18
Black Rice 7.5	17.71^{bc} ±0.10	17.03^{d}±0.39	9.89^{cd} ±0.07	5.59^{bc} ±0.04	3.11^{b} ±0.12	57.89^{b} ±0.14
Brown Rice 2.5	17.64^{bc} ±0.13	14.72^{f}±0.07	10.06^{bd} ±0.09	5.11^{d} ±0.08	3.15^{b} ±0.05	58.03^{ab} ±0.08
Brown Rice 5	17.67^{be} ±0.19	15.02^{e}±0.11	10.22^{b} ±0.47	5.01^{cd} ±0.03	3.19^{b} ±0.08	57.72^{b} ±0.153
Brown Rice 7.5	17.95^{abc} ±0.06	14.92^{f}±0.24	9.75^{e} ±0.05	5.55^{c} ±0.52	2.92^{d} ±0.07	56.11^{c} ±0.45
White Rice 2.5	18.17^{a} ±0.15	14.85^{e}±0.11	10.19^{c} ±0.09	6.06^{a} ±0.06	3.19^{b} ±0.08	55.53^{c} ±0.25
White Rice 5	18.28^{a} ±0.14	14.69^{f}±0.07	9.75^{c} ±0.05	4.95^{ed} ±0.05	2.94^{d} ±0.05	53.74^{d} ±0.47
White Rice 7.5	18.26^{a} ±0.20	14.26^{g} ±0.16	9.77^{d} ±0.07	4.81^{e} ±0.04	2.84^{d} ±0.08	53.68^{d} ±0.91
LSD (0.05)	0.401	0.285	0.305	0.298	0.166	0.698

[abcdef] Means in the same row with different letters were significantly different at $p < 0.05$.

They also quantified anti-nutrients, including phytic acid (745–989 mg/100 g) and oxalates (3.6–13.6 mg/100 g), noting a negative correlation between phytic acid and Fe, which may affect mineral bioavailability. These findings underline the nutritional benefits of black and red rice, advocating for their inclusion in dietary regimes and providing data for future rice breeding programs. Zahra and Jabeen (2020) showed that baked products such as biscuits, cake and crackers were developed from brown rice or blend of brown rice with other ingredients. Biscuits prepared from wheat flour mixed with varying amounts of brown rice flour showed greater contents of ash, fat and crude fiber compared with biscuits prepared from wheat flour only. Therefore, different highly acceptable and healthy food types can be produced from brown rice by optimization of processing conditions. Black rice is used as a major or minor ingredient in paella, rice cakes, fried rice, pancakes, risotto and cereal. Due to its unique functionalities it has become an important constituent of many (Ito and Lacerda, 2019). Zhao *et al.* (2025) highlighted that colored rice varieties (black, brown and red) are nutritionally superior to white rice due to their distinct nutrient and metabolite compositions. Black and brown rice are rich in anthocyanins, proanthocyanins, respectively, and red rice combines both, along with small amounts of carotenoids like lutein and zeaxanthin. These varieties offer higher energy, more amylose and a lower glycemic index than white rice. Black and red rice have higher protein contents, primarily glutelin, which is rich in lysine and highly digestible. They also provide essential amino acids. Black rice is rich in Ca, Mg, P, Zn, K, and Fe, while red and brown rice contains more Se, copper (Cu) and manganese (Mn). Colored rice is widely used in various food products—such as porridge, noodles, desserts, bread and beverages—and serves as a functional food due to its health-promoting properties.

In conclusion, this study demonstrated that colored rice varieties, particularly black and brown rice, possess superior nutritional qualities compared to white rice. Black rice exhibited the highest levels of Ca, Zn and Fe. Brown rice showed higher fiber and K content, enhancing its nutritional profile and making it a good source for dietary improvement.

Physical and cooking quality assessments revealed significant varietal differences. Black rice required the longest cooking time, while white rice showed the highest water absorption and shorter cooking duration. The chemical analysis indicated that whole-grain varieties (black and brown) contained higher protein and fat percentages than white rice, confirming their better nutritional balance. The incorporation of colored rice flours into food products such as mahalabia and cake resulted in noticeable changes in physicochemical characteristics at lower substitution levels (2.5%).

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الملخص العربي

تقييم القيمة الغذائية والخصائص الفيزيائية للأرز الأبيض والملون واستخدامها في تطوير بعض المنتجات الغذائية

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يُعد الأرز (*Oryza sativa* L.) غذاءً أساسياً لأكثر من نصف سكان العالم، إلا أن الاعتماد المفرط على الأرز الأبيض، الذي يفتقر إلى بعض الأحماض الأمينية الأساسية مثل الليسين، يساهم في انتشار سوء التغذية، وخاصة بين الأطفال. هدفت هذه الدراسة إلى تقييم التركيب الكيميائي وتأثير الخصائص الفيزيائية لأنواع الأرز الملون (الأسود والبني) مقارنة بالأرز الأبيض، إضافة إلى دراسة إمكانية استخدامه في تحضير بعض المنتجات الغذائية المختارة لتحسين قيمتها الغذائية. تم تحليل ثلاث أصناف من الأرز وهي: جيزة ١٧٧ (بني)، الياسمين المصري (أبيض)، والأرز الأسود، من حيث خصائصها الفيزيائية والكيميائية وخصائص الطهي، كما تم إدخال دقيق الأرز الناتج منها في تحضير المهلبية والكيك بنسب استبدال مختلفة (٢,٥%، ٥%، و٧,٥%). أظهر الأرز الأسود أعلى نسبة ضرب (٧٤%) وأطول زمن طهي (٢٢ دقيقة)، بينما تميز الأرز الأبيض بأعلى امتصاص للماء. واحتوت الأنواع الكاملة الحبة على نسب أعلى من البروتين (٨,٢٥% و٧,٧٥%) والدهون (٤,٨٨% و٤,٧١%) مقارنة بالأرز الأبيض (٧,٣١% و٤,٤٩%). كما أدى إدخال دقيق الأرز في المنتجات الغذائية إلى تغييرات في محتوى الرطوبة والدهون والنشا والبروتين. حيث زاد الأرز الأسود من الرطوبة والدهون، وساهم الأرز البني في رفع محتوى الألياف، كما أدى استخدام مطحون الارز الملون في المنتجات الغذائية إلى تحسين الصفات الخواص الطبيعية لكل من الكيك والمهلبية.

الكلمات الدالة: الأرز الملون، التركيب الكيميائي، الخصائص الطبيعية.