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# Black rice/forbidden rice a nutrient-dense diet

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**Abstract**
Black rice, also known as forbidden rice or emperor's rice, is a nutrient-rich alternative to conventional white rice, celebrated for its unique dark color and exceptional health benefits. Its distinct hue is attributed to its high anthocyanin content, a powerful antioxidant known for its anti-cancer, anti-inflammatory, and anti-obesity properties. Rich in fibers, vitamins, minerals, proteins, and bioactive compounds, black rice serves as a functional food with potential therapeutic applications. Key bioactive components, including cyanidin-3-glucoside, peonidin-3-glucoside, and tocopherols (vitamin E), contribute to its antioxidant and free radical scavenging abilities, which mitigate oxidative stress and reduce the risk of chronic diseases such as cardiovascular disorders, diabetes, atherosclerosis, and hepatic conditions. Despite its nutritional advantages and applications in nutraceuticals and functional food formulations, black rice cultivation remains limited, primarily to India's northeastern region. Expanding its production across diverse agro-climatic zones, supported by advancements in agronomy, breeding, and crop protection, is essential for wider availability and commercialization. This paper highlights the nutritional profile, health benefits, and bioactive potential of black rice, advocating its inclusion in daily diets and its role as a promising superfood to enhance dietary diversity and address global health challenges.

**Keywords:** Black rice, functional food, nutritional potential and global health benefits etc.

## Introduction
Black rice, often referred to as forbidden rice, is gaining recognition as a superfood or nutrient dense diet due to its impressive nutritional profile and health benefits. Forbidden rice earned its name because it was once reserved for the Chinese emperor to ensure his health and longevity, and forbidden to anyone else. The distinctive purplish-black color of black rice comes from its high anthocyanin content, a powerful antioxidant. Research by Japanese scientists revealed that a genetic mutation affecting anthocyanin production led to the emergence of black rice in a subspecies of rice. This trait has since been replicated and transferred through cross-breeding, allowing for the cultivation of black rice in various rice species. Rice (*Oryza sativa* L.) is a staple crop that serves as a primary food source for a significant portion of the global population, particularly in South Asia. Among its diverse varieties, both wild-pigmented and white rice are cultivated extensively on many Indian islands. Pigmented rice is classified into black, brown, red, and white categories based on the pigments present in the grains, all of which belong to the genus Oryza (Gross *et al*., 2009) [14]. For centuries, Asian countries such as China, Korea, India, Thailand, and Japan have consumed black rice, which historically held a prestigious status. During the imperial period in regions like China and Indonesia, black rice was reserved for royalty and elite classes, often used as a tribute food. Common people were prohibited from cultivating, storing, or consuming black rice without official permission (Kushwaha, 2016) [24]. Valued for its rarity and exceptional nutritional properties, black rice was believed to promote longevity and health in ancient times.

Black rice is a traditional, glutinous rice variety with a distinct pigment and exceptionally high anthocyanin content concentrated in its outermost bran layer (Kushwaha, 2016) [24]. Globally, nearly 200 varieties of black rice are cultivated (Biswas, 2018) [5]. China leads black rice production, accounting for 62% of the global output, followed by countries like India, Indonesia, Sri Lanka, and Thailand, with Thailand ranking fifth globally in black rice cultivation (Amagliani *et al*., 2016; Pengkumsri *et al*., 2015) [2, 30].

In India, black rice varieties are locally abundant, particularly in the northeastern states of Mizoram, Manipur, Assam, and Meghalaya. In Manipur, black rice is known as *Chakhao*, meaning "delicious," with specific varieties such as *Chakhao Ambi*, *Chakhao Angouba*, *Chakhao Poireiton*, and *Chakhao Pungdol Ambui*. Globally, black rice is referred to by various names, including "Imperial Rice," "Forbidden Rice," "Luck Rice," and "King's Rice" in China, *Kalabati* in Odisha, *Kavuni* in South India, and *Kola Saul* in Assam (Mazumdar *et al*., 2022; Kumari, 2020) [26, 23]. The primary carbohydrate in rice is starch, which constitutes 98–99% of its dry weight. Starch is composed of two polysaccharides: amylose, with a lower molecular weight, and amylopectin, with a higher molecular weight. These components are linked by α-1,4 and α-1,6 glycosidic bonds, contributing to the structural and functional properties of rice starch (Amagliani *et al*., 2016) [2].

## Origin and Cultivation of Black Rice

Black rice, known for its striking color and rich nutritional profile, has a complex history rooted in various regions of Asia.

- **Historical Background**

The exact origins of black rice are somewhat unclear, but it has been cultivated for centuries in several Asian countries. Notably, in India, the black rice variety called "Chakhao Amubi" is grown in Manipur. The name translates to “Delicious Black Rice,” highlighting its esteemed status in local cuisine.

- **Geographic Distribution**

Black rice is primarily grown in Southeast Asian countries, including: India: Particularly in Manipur, Indonesia, Thailand & China. Due to its growing popularity in Western countries, black rice is also being cultivated in small amounts in the Southern United States.

## Cultivation Practices

Black rice thrives in warm, humid climates and is typically grown in flooded fields, similar to other rice varieties. Farmers often use traditional methods, but modern agricultural practices are also being introduced to increase yields.

## Types and Varieties of Black Rice

Black rice comes in several unique varieties, each with distinct characteristics and culinary uses. Here are some of the most notable types:

1. **Black Japonica Rice**
- **Description:** A hybrid of black short-grain rice and mahogany medium-grain rice, typically grown together.
- **Flavor:** Earthy with a mild, sweet spiciness.
- **Uses:** Great for salads, side dishes, and as a base for various cuisines.

2. **Black Glutinous Rice**
- **Also Known As:** Black sticky rice.
- **Description:** A short-grain rice that is sticky when cooked, with unevenly colored grains.
- **Flavor:** Sweet and nutty.
- **Uses:** Commonly used in desserts and sweet dishes across Asia, such as rice puddings and traditional cakes.

3. **Italian Black Rice**
- **Description:** A long-grain rice that combines Chinese black rice with Italian rice varieties.
- **Flavor:** Rich and buttery.
- **Uses:** Ideal for risottos and other Italian dishes, providing a unique color and flavor profile.

4. **Thai Black Jasmine Rice**
- **Description:** A medium-grain rice that combines Chinese black rice with jasmine rice.
- **Flavor:** Subtle floral aroma when cooked, similar to traditional jasmine rice but with a nuttier taste.
- **Uses:** Pairs well with savory dishes, especially in Thai cuisine, enhancing both flavor and presentation.

## Nutritional quality

Rice (*Oryza sativa* L.) is a staple cereal crop consumed by the majority of the world's population. It belongs to the family Poaceae (grasses). The rice grain consists of two primary fractions: the hull and the caryopsis, which together account for 20% of the total grain weight (Bielecka *et al*., 2021) [32]. The hull, composed of two specialized structures called the lemma and palea, encloses the seed and provides protection. It is rich in silica and cellulose.

Upon removal of the hull, the caryopsis is exposed, which consists of the bran, endosperm, and germ. The germ, making up 2–3% of the total rice grain weight, is a nutrient-dense component containing minerals, vitamins, fibers, proteins, and phytochemicals. During the milling process, the bran layer is removed, transforming brown rice into white rice. The bran of black rice is particularly rich in dietary fiber, essential amino acids, minerals, functional lipids, phenolic compounds, γ-oryzanols, tocopherols, tocotrienols, phytosterols, phytic acid, and other phytochemicals (Kushwaha, 2016) [24]. For black rice, milling typically removes a smaller portion of the bran to retain its nutrient profile.

The endosperm of black rice is a significant source of carbohydrates, primarily starch, while the outer sub-aleurone layer is rich in protein Mau *et al*., 2017. The starch in black rice consists of two polysaccharides: amylose, which is linear, and amylopectin, which is highly branched. In non-glutinous rice varieties, amylose constitutes 10–30% of the starch, with amylopectin forming the majority. In contrast, glutinous rice has an amylose content that is very low (<2%) to low (10–20%), with intermediate (20–25%) and high (25–33%) levels observed in non-glutinous varieties (Duyi *et al*., 2017) [12]. Variations in grain composition may arise due to factors such as variety, environmental conditions, processing, storage, and geographic location.

Black rice is particularly suitable for individuals with celiac disease as it is gluten-free, low in fat, sugar, and cholesterol, and serves as a good source of essential amino acids, free fatty acids, sterols, and diglycerides. Furthermore, the saturated fatty acid content (73.40%) in black rice exceeds that of unsaturated fatty acids (25.40%) (Frei & Becker, 2005) [13].

**Table 1:** Nutritional superiority of black rice over all the other types of rice (Serving size: 100 g)

| Rice | Protein | Iron | Fiber |
|---|---|---|---|
| Polished White Rice | 6.8 g | 1.2g | 0.6g |
| Brown Rice | 7.9 g | 2.2.g | 2.8 g |
| Red rice | 7.0 g | 5.5 g | 2.0 g |
| Black rice | 8.5 g | 3.5g | 4.9 g |

## Nutritional Profile of Black Rice

Black rice is celebrated not only for its striking appearance but

also for its impressive nutritional content. Here's a closer look at its benefits:

**Key Nutrients**

1. **Amino Acids:** Black rice contains 18 different amino acids, making it a valuable source of protein for vegetarians and those looking to boost their protein intake.

2. **Vitamins and Minerals**:

- **Copper:** Important for iron metabolism and overall health.
- **Carotene:** Contributes to eye health and acts as an antioxidant.
- **Essential Vitamins:** Includes various B vitamins that support energy metabolism and overall well-being.

3. **High in Anthocyanins:** The unique purplish-black color of black rice is due to its high levels of anthocyanins, powerful antioxidants that help combat oxidative stress and inflammation in the body.

**Health Benefits of Black Rice**

Black rice, a potent source of anthocyanins, plays a crucial role in reducing inflammation and cholesterol levels (Duyi *et al*., 2017) [12]. Anthocyanins, the major polyphenol pigments in black rice, act as antioxidants, scavenging reactive oxygen species (ROS) and reactive nitrogen species (RNS), which are byproducts of oxidative stress. These reactive species are associated with age-related diseases such as atherosclerosis, diabetes mellitus, and cancer. Black rice, as a natural antioxidant, helps prevent oxidative damage to biological molecules such as lipids, proteins, and DNA, thereby reducing the risk of carcinogenesis, aging, and inflammation Thanuja & Parimalavalli, 2018 [36]. Extracts from five pigmented rice varieties—DZ 78, Jumlalocal-1, LK1-3-6-12-1-1, Elwee, and LK1A-2-12-1-1—showed antitumor activity by inhibiting Epstein-Barr Virus Early Antigen (EBV-EA) activation induced by the tumor promoter 12-O-tetradecanoylphorbol-13-acetate. This study inferred that pigmented rice, unlike non-pigmented varieties, can prevent phorbol ester-induced tumor promotion in B95-8 marmoset lymphoblastoid cells (Samyor *et al*., 2017) [31].
Recent findings by Mapoung highlight the potential of black rice anthocyanins, particularly cyanidin-3-glucoside (C-3-G) and peonidin-3-glucoside (P-3-G), to combat inflammation and infections. These anthocyanins inhibit the activation of NF-κB and the NLRP3 inflammasome pathway, reducing cytokine secretion and inflammatory gene expression in lung epithelial tissues and macrophages, thereby potentially addressing infections caused by the SARS-CoV-2 spike glycoprotein. Anthocyanins in black rice prevent cardiac diseases and atherosclerosis by inhibiting the accumulation of low-density lipoproteins (LDL) in arterial walls, as reported by Panda *et al*. (2022) [29]. These findings underscore the multifaceted health benefits of black rice, making it a functional food with potential therapeutic applications. The consumption of black pigmented rice is associated with a reduced risk of various chronic diseases due to its rich composition of bioactive compounds such as anthocyanins, proanthocyanidins, γ-oryzanol, and ferulic acid. These compounds are believed to stimulate the secretion of the anti-inflammatory enzyme superoxide dismutase, which plays a key role in mitigating oxidative stress and inflammation (Verma & Srivastav, 2020; Thanuja & Parimalavalli, 2018) [38, 36]. Anthocyanins derived from black rice into the diet to enhance antioxidant and anti-inflammatory activities in patients with cardiac disorders. Their study revealed that patients with coronary heart diseases benefited significantly from this intervention, as it led to an increase in plasma antioxidant levels (Verma and Srivastav 2020) [38]. This, in turn, resulted in reduced inflammation, underscoring the therapeutic potential of black rice in managing

Black rice is not just a visually appealing grain; it also offers numerous health benefits thanks to its rich nutrient composition. Here are some key advantages:

1. **Rich Source of Antioxidants**

- **High Anthocyanin Content:** The deep black purplish color of black rice indicates its high antioxidant properties, particularly from anthocyanins, which help combat oxidative stress.
- **Vitamin E:** This important antioxidant supports eye, skin, and immune health, contributing to overall wellness.

2. **Protects Heart Health**

- **Atherosclerosis Prevention:** Black rice has been shown to decrease the formation of atherosclerotic plaque in the arteries, which is crucial for maintaining cardiovascular health.
- **Reduced Risk of Heart Disease:** By keeping arteries clear, black rice can help lower the risk of heart attacks and strokes.

3. **Supports Liver Detoxification**

- **Detoxification Benefits:** Regular consumption of black rice can aid in detoxifying the body, particularly the liver, by helping to eliminate harmful toxins.
- **Regulation of Fat Metabolism:** The antioxidant activity of black rice extract supports fatty acid metabolism, lowering triglyceride and total cholesterol levels, which can help prevent fatty liver disease.

4. **Prevents Diabetes**

- **Slow Digestion:** The high fiber content in black rice aids in slower digestion, which helps ensure that sugars are absorbed gradually. This prevents sharp spikes in blood sugar levels.
- **Blood Sugar Regulation:** By maintaining stable insulin levels, black rice may help reduce the risk of developing type 2 diabetes, making it a smart choice for those monitoring their blood sugar.

5. **Protects Against High Blood Pressure**

- **Cardiovascular Health:** The dietary fiber found in black rice contributes to heart health by helping to maintain normal blood pressure levels.
- **Lipid Regulation:** Regular consumption of black rice can lower lipid levels, further supporting cardiovascular function.
- **Overall Benefits:** The combination of fiber's effects on body weight, glucose metabolism, and chronic inflammation can provide comprehensive protection against hypertension.

**Fights cancer**

The anti-cancer properties of black rice, particularly attributed to its anthocyanin content, highlight its potential as a valuable addition to a health-conscious diet. While more research is needed to fully understand its effects in humans, incorporating black rice may offer promising benefits for cancer prevention

## Conclusion

Black rice, often referred to as forbidden rice or emperor's rice, is a nutritious alternative to white rice that can be seamlessly integrated into various dishes. Its most notable antioxidant, anthocyanin, not only contributes to its unique color but also offers significant health benefits, including anti-cancer properties. Traditionally, black rice has been served to pregnant women to ease childbirth and has been used as a remedy by individuals with diabetes. black rice is storehouse of fibers, vitamins, minerals, proteins, bioactive compounds and it also contain cyanidin-3-glucoside and peonidin-3- glucoside (anthocyanin) and Vit E i.e. tocopherols. Black rice being a potent source of antioxidants, has free radical scavenging properties which are generated due to oxidative stress in body. Thus, incorporation of black rice in daily diet can be a healthy choice as it has potential to reduce several diseases *viz* cancer, inflammation, atherosclerosis, obesity, diabetes, constipation, hepatic disorders etc. Black rice variants' bioactive components have aroused fresh attention, improved their application in nutraceuticals, and included the food industry. The antioxidant and free radical scavenging abilities of anthocyanins in coloured rice make their prospective use in food formulations quite evident. The mechanisms of the usefulness of the compounds in black rice varieties and their various roles, such as antioxidant and free radical scavenging, anti-allergic, anti-atherosclerosis, anti-influenza, anti-obesity, and antitumor activities against many degenerative and chronic diseases of humans, will be clarified by further research and development work. Despite its advantages, the cultivation of black rice is largely confined to the Manipur region. To fully harness its potential, it's essential to explore its cultivation in other parts of India. This expansion should be accompanied by comprehensive studies on agronomy, protection, quality, and breeding to ensure successful commercialization and sustainable farming practices. By doing so, black rice can become a more widely available superfood, benefiting more people and enhancing dietary diversity.

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