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Pigmented Rice: A Source of Health and Longevity

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Rice of different varieties forms the staple food of more than half of the population in the world and is the leading cereal crop in many developing countries of the world. About half of the world population consumes rice as their major source of carbohydrate however it is also consumed as a source of protein in many countries. Rice comes in many shapes, sizes and color and thus its nutritional quality, cooking and uses vary accordingly. It is not only the white rice which contributes to these production figures, but it are available in many colors and pigments including black, purple, brown and red. The yellow, green, brown, red, purple and black colors of the rice have neutraceutical properties and hold the potential to promote health and improve metabolism. Black rice, also called "emperor's rice," has a thin layer of black bran, due to the presence of the purple/ black pigment biochemically termed as 'anthocyanin'. It is a rich source of antioxidants along with other nutrients including B vitamins (thiamine, niacin), vitamin E, magnesium, phosphorous, iron and

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dietary fibers. Similar to normal white rice, pigmented/ black rice is also glutinous and is relished for its nutritional significance of being low in fat, sugar and salt it is also free from gluten and cholesterol. Not only the historical evidence but modern research findings also support the claim of pigmented rice being 'super food' of twenty-first century. It has wide health benefits including lowering risk of obesity, anti-ageing, anti-cancerous, anti-diabetes and many more. Its consumption even in limited amounts acts as a savior from many serious diseases and illnesses. Due to its nutritional composition and various health benefits, it is considered as a functional food. The presence of anthocyanin, the pigment that imparts it a specific colour and holds antioxidant properties supports health and longevity. The present review reflects the nutritional profile and significant benefits of pigmented rice including its food uses so that the commodity can be popularized and utilized by the population for gaining various health benefits.

Keywords: Pigmented rice; black rice; nutritional importance; health benefits; food uses.

1. INTRODUCTION

Rice of different varieties forms the staple food of more than half of the population in the world and is the leading cereal crop in many developing countries of the world. About half of the world population consumes rice as their major source of carbohydrate however it is also consumed as a source of protein in many countries. Asian continent contributes approximately 95% of the rice [1-3]. According to FAO reports about 175 countries and territories consume rice as major food and the consumption of rice in these countries ranges between 100-200kg per person per year. Also, some nutrition boosting programs including ‘Harvest plus’, biofortification with minerals like zinc, iron, iodine and selenium etc target rice as a convenient source to introduce in the diet [4-8]. Rice comes in many shapes, sizes and colors and thus its nutritional quality, cooking and uses vary accordingly. It is not only the white rice which contributes to these production figures, but it are available in many colours and pigments including black, purple, brown and red. Besides affecting the acceptability of this rice, the pigment or the color of the rice, which is usually due to the dominance of pigment ‘anthocyanin’ affects its nutritional and therapeutic quality as well [9]. The yellow, green, brown, red, purple and black colors of the rice have neutraceutical properties and hold the potential to promote health and improve metabolism. These varieties of rice contain various micro and macro nutrients including secondary metabolites [10]. The quantity of anthocyanin in the pericarp (the natural covering of paddy) affects the appearance of the grain from purple to black. [11]. However, amongst healthconscious consumers, pigmented rice, especially the purple and black pigmented is highly rated [12].

Rice comes from the species *Oryza sativa* and black rice is a member of same species with its scientific name *Zizania aqatica* [12]. It is known by many regional and local names in different communities of the world. History reveals that it is most commonly referred to as ‘forbidden rice’ (especially the purple rice), king's rice, prized rice, heaven rice and imperial rice [13]. As the other names indicate, the rice was considered highly nutritious and had therapeutic properties for which it was only served to the Kings and Royals and was forbidden for consumption by the local population [14]. It is also famous by other names in different states or regions as in Manipur (India) it is popular as ‘Chak-hao Ambi’ where in local language Chak-hao and ambi mean 'delicious' and 'black’ respectively and thus ‘delicious black rice’. Similarly in the state of Odisha it is available as ‘Kalabati’ where in local language ‘kali’ refers to 'black’ and ‘bati’ refers to 'rice' [15]. Black rice, also called "emperor's rice," has a thin layer of black bran, due to the concentration of purple/ black pigment biochemically termed as ‘anthocyanin’. It is rich in antioxidants along with other nutrients including B- vitamins, E- vitamin, phosphorous, magnesium, thiamine, niacin, iron and dietary fibers. Alike common white rice, black/ pigmented rice is also sticky (glutinous) and is relished for its nutritional significance of being free from gluten and cholesterol and less sugar, fat and salt. It is usually sold unmilled with bran intact, which contains the black/ purple pigment. This pigment turns purple with indigo finish and shiny appearance with smooth, firm texture and nutty flavor [14]. Not only the historical evidence but modern research findings also support the claim of pigmented rice being 'super food' of twenty-first century. Nowadays it is considered as a functional food [16]. It has wide health benefits including lowering risk of obesity, anti-aging, anti-cancerous, anti-diabetes and many more. Its consumption even in limited amounts acts as a savior from many serious diseases and illnesses.

2. ORIGIN AND CULTIVATION

India is amongst the leading producers of rice and the average area of rice cultivation in India is approximately 46.38 Million hectares [17]. Portion of rice in Indian serve includes about 689kcal/capita/day as compared to 780kcal/capita/day in the Asian subcontinent. Thus India becomes largest country in respect of energy consumption from agriculture with rice being the highest contributor [18]. Approximately 40,000 rice varieties are cultivated worldwide, however, two species namely *Oryza sativa* viz., the Asian rice is most popular worldwide. Another species *Oryza glaberrima* viz., the African rice is confined to Africa only. Further, two important sub-species of *Oryza sativa* i.e., Indica and Japonica are commonly cultivated and consumed as per the requirements of the cuisines. Indica is the typical long grain rice and Japonica is the typical round-grain rice [19]. Indica is more common in Indian subcontinent whereas Japonica is mainly cultivated in Australia, China, Taiwan, Korea, the European Union, Japan, Russia, Turkey and the USA.

3. ORIGIN

Rice belongs to the family *Poaceae* and its most common species is *Oryza sativa*. It has a history of origin in India with cultivation of more than 10,000 years ago in the river valleys of South and South-east Asia [20]. In India, rice is said to be domesticated during Indus Valley civilization, viz., 3000-1500 BC [21]. Also, evidence from the site of Lahuradewa, Uttar Pradesh, situated in the middle Ganges plains dating to 6409 BC, endorses the cultivation of rice in India before 4000 years ahead of it [22-23]. Before the Green Revolution or until 1970, India harbored more than 1,10,000 rice varieties. It included many colored and pigmented rice varieties. However with the onset of Green Revolution, the cultivation shifted to monoculture and hybrid crops [24] and the original crops and many of its varieties vanished. New paddy varieties with polished white shine overtook the colorful varieties, which were otherwise considered beneficial for health [25]. In Keelapoongudi village (Taluk: karaikudi) of Tamilnadu, the rice is cultivated by the name of 'kavuni rice' and is consumed by local people.

Black or pigmented rice of numerous varieties is believed to be cultivated in South-East Asian countries with China, India and Thailand being the major producers [26] followed by Bangladesh, Vietnam and Indonesia. Presence of Cyanidin-3-glucoside (an anthocyanin) makes the rice look black in color and hence is referred [27,28]. During the period of Chinese reign, it is assumed that people of China consumed black rice with a belief to live healthier and longer. They referred it as 'luck rice' as they believed that its consumption will make them live longer. However, in some areas of the world, black color of the commodity was considered ‘dirty’ and the population refused to consume it. Later with the development in science and technology, it was concluded that paddy undergoes no mutational changes as well as no accumulation of pigments hence it remains white and on the other hand accumulation of tannins gives it a red/brown color and anthocyanin gives it a black color [29]. Scientifically Kala4 enzyme undergoes mutation and causes dense accumulation of brown pigment-anthocyanin which produces dark colored rice called ‘black rice’ [30].

4. CULTIVATION

Pigmented Purple colored rice holds the history of cultivation in Asian sub-continent. China, India, Indonesia, Korea, Japan, Vietnam, Laos, Sri-lanka, Thailand and Nepal are major rice pigmented rice producing countries [31-35] alongwith Brazil and some other countries. Recently, pigmented rice is gaining popularity for cultivation in other countries as well. Some new varieties of pigmented rice have been introduced in the international markets from Australia, Italy, France and Russia [36-39]. As per literature available [40], black or purple rice has been divided into many types and varieties as follows:

a) **Japonica Black Rice**: It contains both short black and medium grained mahogany colored rice with sweet, spicy and earthy flavor.
b) **Italian Black Rice**: The rice has a rich buttery flavor and holds the characteristics of both Italian and Chinese rice. It is usually long gained rice with black color.
c) **Black Glutinous/ Sticky Rice:** It is dominant to Asia and as the name suggests it is sticky textured rice with uneven black color on the grain. Due to its pleasant sweet taste and aroma it is commonly used for preparing sweet dishes including porridges and others.
d) **Thai Black Jasmine Rice**: The rice has its origin in Thailand which holds a delicate jasmine like aroma. The grain size is medium and has a combination of Chinese black rice with floral (jasmine) aroma.

Another portion of dominating black rice from India includes Kalabhat, Kalanamak and Manipuri black rice.

3. NUTRITIONAL PROFILE

The raw rice or paddy is rough due to the intact hull and husk around the rice caryopsis in the unpolished rice [41]. The white rice, usually consumed by a large population is highly polished and refined to get that texture and color. Almost all the covering layers of the raw paddy including bran, germ and aleurone layer (rich source of dietary fibres and other nutrients) are removed [42]. Most of the nutrients including proteins, minerals and vitamins are leached out with the washing-off of each layer and the final polished, refined grain contains nothing more than the starch.

Pigmented or black rice on the other hand is rich in both, macro and micro nutrients. In addition to carbohydrates, it is an excellent source of high quality plant-based proteins and fibers. It supplies highest amount of antioxidant alongwith good quality essential amino acids, viz., tryptophan and lysine. It is a good source of B-vitamins and folic acid and minerals like calcium, phosphorous, zinc, iron and selenium are abundantly present. Antioxidant content of pigmented rice is approximately six times higher than the normal brown (unpolished rice) rice. Anthocyanin, the major pigment responsible for the color of the rice, is estimated to be around 327.60mg/100g. Amongst many cultivars of rice, pigmented rice or black rice have a higher content of phenolic compounds. Accordingly, one serve or 50g of black rice provides approximately 160 calories, 5g protein, 2g fibers and 1g of iron. Also, approximately 50g brown rice is capable of meeting 35 per cent of the daily requirements of micro minerals including selenium, copper, zinc and manganese. Thus the nutritional profile of black or pigmented rice is far better than normal white polished rice with additional health benefits [43-50]. However, the nutritional content of grain varies with the type of soil, processing methods adopted and others.

4. HEALTH BENEFITS

The wide and varied use of Pigmented rice in curing health issues has found its mention in the traditional pharmacopeia of Asia [51]. In a comparison amongst the pigmented red rice varieties from Srilanka, Thailand and black rice from China it was reported that red rice from Thailand was far better than the Srilankan red rice but black rice was more superior than all [52].

Health benefits of black rice has gained popularity in recent years and its role in both the prevention and treatment of diseases like hypertension, diabetes, heart disease and even cancer has been recognized. It has been taken as a food that promotes the quality of life as well as extends the life span [53,54]. The traditional Chinese way of therapy widely used black rice in treating broken bones, eyesight, kidney functions and improving blood circulation [55,56]. The antioxidants in black rice are found to be supportive in strengthening the immune system as well as enhancing the memory [52,57]. Pigmented rice is considered reservoirs of phytochemicals viz., phenolics, flavonoids, alkaloids, carotenoids and compounds carrying organosulfur and nitrogen, coumarins and tannins. The biochemical compounds cyanidin-3-O-β-glucoside and peonidin-3-O-β-glucoside, basically the anthocyanins and tocols identified in black rice [58] are identified to have inhibitory activity on aldose reductase which is used in the treatment of chronic diabetes and neuropathy caused due to diabetes. Also abundance of Cyanidin-3-O-β-D-glucopyranoside in pigmented rice is taken as a functional ingredient as it guards the body against the occurrence of neurodegenerative disorders and cytotoxicity. It inhibits the activity of glycogen phosphorylase and exhibit both scavenging and antioxidant activity, both in-vitro and in-vivo conditions [59-60]. Anthocyanins present in black rice have been reported to improve mental agility and reduces the symptoms of depression, dementia, Alzimer's disease. It also helps to boost memory and avert the conditions causing cognitive ageing at a premature stage [61].

In addition to many micro nutrients of high value, pigmented rice is a rich source of dietary fiber. Also, the fiber content of black rice is double the amount of fiber present in brown or other pigmented rice. These fibers tend to digest slowly and take time to pass through the stomach. This aids in reducing the hunger pangs and anonymous eating thereby reducing the food and calorie intake and maintaining or losing weight becomes easy. It improves gut health by increasing the bulk and binding the toxins to remove them effortlessly from the body [62,63]. These dietary fibers also help to improve cardiovascular health and prevent heart ailments by reducing plaque build-up in the arteries and

thus the hardening of arteries, which could be a major cause of heart failure, is prevented. It also lowers triglycerides and improves HDL levels in the blood which maintains heart health by controlling blood pressure, blood sugar and protects from heart stroke [64]. Protein in black rice is also been reported to be superior as compared to white rice [65]. Thus looking at tremendous health benefits provided by pigmented rice it was being appreciated by the ancestors including kings and emperors and those considered expert in medicine and pharmacy.

5. FOOD USES

Functional and health benefits of pigmented rice and black rice have made it a choicest food for many dieticians and nutritionists. Many studies have been conducted and reported for utilization of pigmented rice as food or as a part of food material. The color of the rice itself acts as the matter of acceptance or rejection of pigmented as whole in any cuisine. Also, being expensive as well as not so common in non-rice areas, black rice is not so commonly consumed by general population and has now become as a delicacy. However the nutritional and health benefits of pigmented rice is continuously gaining attention of nutritionists and food technologists and many new kinds of preparation have come up with rice as an ingredient. Especially the bakery products including breads, cakes, muffins, pasta and many more have been introduced for consumers, who are willing to get benefitted by pigmented rice.

The tinted color of the rice brown/ black is because of anthocyanins, the major contributor has been graded as a safe and natural colorant for food. However, all the varieties of black/brown rice are not appropriate for incorporation in all kinds of products due to their varying functional and cooking qualities. Many studies have come up with the product preparation using pigmented flour as a replacement of regular flour and the results as per nutritional profile, quality parameters of the product and acceptability scores of the products are very promising. [66] developed a mathematical model to assess the digestion rate of bread prepared with the incorporation of black rice flour. The results revealed that replacement of wheat with 2 per cent and 4 per cent black rice flour reduced digestion rates thus validating health claims of black rice flour. Further, it was evident that black rice flour and its replacement with regular flour be taken as functional food especially for diabetics. Results also revealed that incorporation of flour at 2 per cent did not affect the characteristics features of the bread but incorporation at the rate of 4 per cent altered its crumb structure and made it hard.

A twenty per cent replacement of wheat flour with black rice flour did not affect the sensory attributes but improved the functional pro flour properties of dough. Incorporation of black rice flour increased the pH and moisture content of the flour. The typical color of the rice, as black, affected the acceptability of the cookies with respect to its color but it improved the spread ratio and texture of the cookie. The high fiber content of rice flour retained more moisture and the using black rice flour upto 20 per cent substitution produced acceptable quality cookies [67,68]. Further 25, 50 and 100 per cent substitution of rice flour (purple) enhanced protein digestibility and reduced rates of starch digestion. The glycemic level of biscuits prepared from 100 per cent purple rice flour was very low and besides the sensory scores for color and overall acceptability scores of biscuits with 25 and 50 percent replacement were in appreciable range [69]. Hence study concluded that the biscuits with purple rice flour can be recommended as functional food for people with high glucose levels and these can also be a part of their meal as it helps to lower the digestion rates of starch thus maintaining blood glucose levels. Extruded pasta products from black rice flour improved both, water absorption and water solubility index as black rice flour swelled with addition of water. However, exposure to high heat during extrusion process degraded anthocyanin content and reduced antioxidant activity [70]. In another event black rice flour was incorporated in wheat flour at 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 per cent (w/w) for the preparation of chiffon cakes. The incorporation increased the specific gravity, hardness of crumb and crust of the cakes. The structure became dense with incorporation and its color and chewiness also decreased including a decrease in volume, springiness, resilience and porosity of the final product. The incorporation of black rice flour improved the antioxidant activity as well as the nutritional profile of the cakes. However the increase in the ratio of black rice flour reduced the overall acceptability of chiffon cakes severely affecting its colour scores which decreased with increasing incorporation [71].

In an attempt of utilizing black rice bran powder in the preparation of noodles, the regular flour was replaced with black rice bran powder in the

ratio of 0, 2, 5, 10 and 15 per cent. The results revealed that the substitution improved moisture, protein, lipid and ash content. However the antioxidant activity of noodles was higher in dried noodles which decreased when exposed to heat while cooking. The sensory scores for color were adversely affected by the substitution as the black rice bran incorporation enhanced the dark color in noodles. Substitution of rice bran flour hardened the texture of noodles and increased its cohesiveness [72].

6. CONCLUSION

From ancient rein Pigmented or black rice was considered as Emperor's rice, King's rice as it was believed to have such qualities which had benefits for healthand enhanced longevity. Today researchers and scientists have found the scientific base of these claims and refer it as a nutraceutical or functional food. Pigmented or black rice is a rich source of anthocyanin which gives it the characteristic color. Additionally many other phytochemicals, macro and micro minerals, vitamins etc make it a better choice for nutritionists. Today it is cultivated in many parts of the world for its high demand amongst healthconscious people. It is considered beneficial for diabetics, heart patients, renal health, and weight conscious and for maintaining general health. The rice is being utilized as such in place of white rice or is converted to flour for incorporation with other flour for preparing variety of other food products like bread, cake, pasta, noodles and many more. The sticky varieties of pigmented or black rice are also utilized in the preparation of supplements. The pigmented rice could be a wonder food for upcoming generations which are facing a lot of health issues and lifestyle diseases.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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