

# Nutraceutical Potential of Pigmented Rice of North India

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**Abstract:** Rice is a major cereal crop and a staple food in the majority of developing countries. India is second only to China in rice production. Though nearly 40,000 varieties of rice are said to exist, only a few are widely cultivated, milled, and polished at this time. Even though white rice is consumed by the majority of people worldwide, some specialty rice cultivars are also grown. Colored and aromatic rice varieties are among them. When compared to white rice varieties, specialty rice has a higher nutritional profile. Colored rice is high in phytochemicals and antioxidants because of the deposition of anthocyanin pigments in the bran layer of the grain. Rice bran, an underutilized byproduct of the rice milling industry, is high in dietary fiber and has applications in the development of functional foods and other value-added products. Thus, a greater emphasis on specialty rice and its byproducts will not only save it from extinction, but will also contribute to the country's nutrition security because they are high in vitamins, minerals, and polyphenols.

**Keywords:** Rice, Pigmented rice, Polyphenols, Phytochemicals, Health.

## INTRODUCTION

Rice (*Oryza sativa* L.) is a staple cereal crop consumed across the world. It is one of the most economically important cereal crops on the planet. In many civilizations, rice has long been regarded as one of the most important foods. [1] Rice farming is the world's largest source of food. Rice production corresponds to 600 million tons annually. Asian countries contribute about 90% of the world's rice production. Rice fields occupy 11% of all arable land. Rice is grown in more than 250 million fields across Asia. Rice farming has been practiced for over 10,000 years. The majority of the world's population relies on food. It is the most essential source of energy for the impoverished [2]. Rice is a main source of carbohydrates, protein, and other essential elements for billions of people around the world, especially in poor countries. After harvest, rice grain is processed subjected to drying, milling, and packaging, to make it more convenient to consume. In the first step of the milling process, the husk is removed from the whole rice grain or paddy to give whole brown rice grain (BR) that, contains the outer bran layer with a common brown color. To make polished or white rice, the outer bran layer is removed in the second procedure (WR). The layers of bran that contain significant amounts of nutrients and bioactive chemicals are the pericarp, aleurone, sub-aleurone layer, and germ [7] There have been numerous studies evaluating the nutritional quality and potential health benefits of whole BR grain to WR grain. In general, BR has more nutrients than WR in terms of protein, fat, vitamins, and minerals. Bioactive compounds such as phenolic acids, flavonoids, oryzanol, aminobutyric acid (GABA), -tocopherol, and -tocotrienol have also been reported for in the full BR grain. [8] in adequate amount. This is owing to the high concentration of these components in the outer bran layers of rice grains [3]. However, rice type, production environment, geographic origin, and postharvest treatments or processing conditions affect the amounts of these nutrients and bioactive compounds.

## Pigmented rice

Rice is one of the world's most important cereal crops for human consumption. Some varieties have coloured testa (black, purple, or red), which can be seen after the hull (floral bracts) covering the caryopsis is removed. Earlier, although red (reddish-brown) caryopses are primarily seen in wild rice varieties however, white kernel type rice varieties were mostly preferred While coloured cultivars are not extensively produced or consumed in Western countries, however these are widely grown in Asian countries. Black rice is black coloured rice which turns deep purple when cooked. Such colour of the rice is due to presence of anthocyanin. The cultivars are widely grown across Asia in India, black rice is grown in Manipur as "Chakhao Amubi" rice This rice is used to prepare desserts, bread, cake, noodles and porridge. Red rice's can be found as wild, weedy, or cultivated varieties, with dark or light-coloured husks covering the red kernels. In some areas of India, red rice is considered highly nutritive and medicinal. The rice is eaten as whole grain. Red gunja is preferred for making bread and chapati [5]. Glutinous rice is used in making puttu in South India. In Himachal Pradesh, India, Jatu red rice is prized for its aroma and taste. Red rice is used to make vinegar, tart, cosmetics, red kojic, and red rice yeast, which is utilised in Chinese medicine. Brown rice is a whole grain rice containing bran and germ layer with outer hull removed during milling. The brown colour of the rice is due to presence of bran and germ layer. Brown rice starch is used to make ice, custard powder, puddings, gel, and the distillation of drinkable alcohol, among other things. Brown rice bran is found in baked goods such as bread, crackers, cookies, and biscuits.

Rice has three well-known antioxidant chemical groups that have been connected to health benefits: c-oryzanols, polyphenols, and tocols c-Oryzanols, a family of ferulic acid esters of unsaturated triterpenoid alcohols, have been discovered in rice bran. Rice bran oil contains tocotrienols and tocopherols as well Rice polyphenols are made up of phenolic acids (found in white rice kernels) and flavonoids (found in coloured rices) [6]. Although the nature of red grain pigments is unknown, anthocyanin has been related to the colour of purple and black kernels [7]. According to Reddy et al. [7], the presence of a type of polymeric z-molecule termed proanthocyanidins is associated to the appearance of reddish-coloured testa. Malnutrition, anaemia, and exacerbated diabetes have all been linked to the continued usage of white rice as a major food grain ). In this instance, black rice, which is used as a functional

food due to its health benefits, becomes an option. Due to its high nutritious value, therapeutic impact, anti-inflammatory, anti-cardiovascular, anti-atherosclerosis, anti-carcinogenic, and anti-oxidant qualities, black rice has piqued the scientific community [9] interest and gained prominence in recent years. As a result, black rice has the potential to be a useful culinary ingredient. It protects arteries, regulates blood lipids, protects DNA from oxidative damage, lowers cholesterol levels, inhibits cancer cell invasion, and lowers cancer risk/prevents tumours. [11]. Black rice is beneficial to persons with diabetes and Alzheimer's disease [12]. The present rice based diet contains nutritional gaps mainly due to the milling process which removes health promoting compounds present in rice bran. Therefore, less milled or brown rice consumption is highly recommended to achieve nutrition sustainability. Brown rice contains relatively higher amounts of dietary fibre, moderate amount of proteins, unsaturated lipids, micronutrients and several bioactive compounds. Some landraces consumed as brown rice have low glycaemic index properties; hence they might be helpful to counter the growing type II diabetes [15]

### Origin and spread of rice

The most common type of rice, *Oryza sativa*, belongs to the Poaceae family. Rice was commonly grown in North and Northeast Asia's river basins. The Indus valley civilization, which flourished between 3000 and 1500 BC, is primarily credited with domesticating rice in India [6]. However, the evidence of rice cultivation in India has been advanced by 4000 years thanks to the discovery of rice grains and early pottery at the site of Lahuradewa, Uttar Pradesh, which is located in the middle Ganges plains and dates to around 6409 BC [7, 8]. The fact that rice is produced in north-eastern China at latitude 53°N, on the equator in central Sumatra, and at 35°S in New South Wales, Australia, demonstrates rice's exceptional adaptability to its growing environment. In India, it is grown in Kerala below sea level; the majority of rice-growing regions are found at or near sea level as well as in Kashmir at altitudes over 2000 m. Today, every continent other than Antarctica has rice cultivation. [9]

### Important of rice in India

India produces 22.5% of the world's total rice production, it second to China in terms of production. The most important crop in India is rice, which is also the main food source for those who live in the country's eastern and southern regions. In India, rice is valued more than just for its nutritional value since it also has significant spiritual and ritual significance. Because of its ability to sustain life, rice is regarded in Indian culture as a powerful emblem of fertility, prosperity, and auspiciousness. Several rice-related rituals are carried out for various events and celebrations. Women in Tamil Nadu use rice flour to make kolam, a type of geometric pattern, on the thresholds of the houses before dawn. Indian wedding rituals also depend heavily on rice. In the rite known as Dhanpan, the family of the bridegroom brings turmeric, betel, and/or paddy to the home of the bride [10]. Additionally, rice is essential for the events of birth, the introduction of the baby's first solid food at 6 or 7 months old, and adolescence in Kerala and Tamil Nadu. These events are known as godh bhara in North India, valaikaapu in Tamil Nadu, and seemandham in Kerala. In Kerala, flattened rice prepared from the variety Thavala Kannan is offered as a sacrifice. In this way, rice has influenced not only human history, culture, cuisine, and economy, but the growing stage of the rice crop also serves to indicate the passing of time and season. Rice is revered as the foundation of civilization in India [12].

### Rice variety production and market demand

In many different cultural cuisines all around the world, rice is a staple ingredient. According to Ricepedia, Asia accounts for more than 90% of worldwide rice production and consumption, with the current global rice consumption share hovering around 87%. According to the global market scenario for rice, production has risen marginally over time. Compared to feed and other applications, eating rice continues to be the most common use. Rice usage and supply have both slightly increased (Table 1)

Table 1 Details of global rice market (14)

|             | 2014-2015 Million tonnes, milled equivalents | 2015-2016 | 2016-2017, estimate | 2017-2018, forecast |
|-------------|--|-----------|---------------------|---------------------|
| Production  | 490.9  | 491.9     | 501.2               | 502.2               |
| Supply      | 709.2  | 703.8     | 712.0               | 718.4               |
| Utilisation | 494.3  | 492.5     | 497.9               | 503.5               |
| Food use    | 397.2  | 395.6     | 400.9               | 406.7               |
| Feed use    | 18.0   | 18.2      | 17.8                | 17.5                |
| Other uses  | 79.2   | 78.7      | 79.2                | 79.4                |

Similarly, rice is a significant cereal crop and is a staple diet for the vast majority of Indians. One of the main regions for the production of rice is India. Both the Assam red rice and the Himalayan red rice have a position in world trade. Over this time, the output of rice, wheat, and maize has increased gradually, with rice producing the most, followed by wheat (Table 2). The production of other grains, such as sorghum, pearl millet, finger millet, tiny millet, and coarse cereals, has, in contrast, either been stable or has decreased. Both wealthy and poor people, as well as households in rural and urban areas, eat rice. Following the Green Revolution, there was a rise in the per capita net availability of food grains, and rice, along with vegetables, is a component of a balanced diet.

fruits, meat, eggs, and pulses. In 2017, the net availability of rice per person grew to 69.3 kg/year from in 1951, 58.0 kilogramme per year [15, 16]. This general decrease in spending could be the result of households in both rural and urban areas spending more money on non-food products [16].

Table 2 Rice production in India (2009-2017) [1]

**Varieties of rice**

| Crop              | 2009-2010<br>Million<br>tonnes | 2010-2011 | 2011-2012 | 2012-2013 | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017,<br>estimates |
|-------------------|--------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-------------------------|
| Rice              | 89.09                          | 95.98     | 105.30    | 105.24    | 106.65    | 105.48    | 104.41    | 109.15                  |
| Wheat             | 80.80                          | 86.87     | 94.88     | 93.51     | 95.85     | 86.53     | 92.29     | 97.44                   |
| Sorghum           | 6.70                           | 7.00      | 5.98      | 5.28      | 5.54      | 5.45      | 4.24      | 4.74                    |
| Pearl<br>millet   | 6.51                           | 10.37     | 10.28     | 8.74      | 9.25      | 9.18      | 8.07      | 9.86                    |
| Maize             | 16.72                          | 21.73     | 21.76     | 22.26     | 24.26     | 24.17     | 22.57     | 26.14                   |
| Finger<br>millet  | 1.89                           | 2.19      | 1.93      | 1.57      | 1.98      | 2.06      | 1.82      | 1.43                    |
| Small<br>millet   | 0.38                           | 0.44      | 0.45      | 0.44      | 0.43      | 0.39      | 0.39      | 0.44                    |
| Barley            | 1.35                           | 1.66      | 1.62      | 1.75      | 1.83      | 1.61      | 1.44      | 1.79                    |
| Coarse<br>cereals | 33.55                          | 43.40     | 42.01     | 40.04     | 43.29     | 42.86     | 38.52     | 44.39                   |
| Total             | 203.45                         | 226.25    | 242.20    | 238.79    | 245.79    | 234.87    | 235.22    | 250.98                  |

Only two primary species, *Oryza sativa*, or Asian rice, and *Oryza glaberrima*, or African rice, are grown extensively globally among the 40,000 different kinds of rice. Worldwide, *Oryza sativa* agriculture is practised, whereas *Oryza glaberrima* cultivation is limited to Africa [17]. There are two main subspecies of *Oryza sativa*: The Japonica, which has spherical grains, and the Indica, which has long grains. The majority of countries that grow and consume japonica rice include Australia, China, Taiwan, Korea, the European Union, Japan, Russia, Turkey, and the United States. In Asia, Indica rice cultivars are commonly grown [17]. Basmati, Joha, Jyothi, Navara, Ponni, Pusa, Sona Masuri, Jaya, Kalajiri (aromatic), Boli, Palakkad Matta, etc. are some of the popular rice kinds grown in India. Himalayan red rice, Matta rice, Kattamodon, Kairali, Jyothy, Bhadra, Asha, Rakhshali from Kerala, Red Kavuni, Kaivara Samba, Mappillai Samba, Kuruvi Kar, Poongar from Manipur, etc. are some examples of the coloured type rice.

### Processing of rice

The primary method of processing rice is milling, which entails removing the hull and all or part of the bran layer to transform paddy into rice. A vital step in the rice-making process is milling, which removes the husk and bran to create an edible white rice kernel free of contaminants. All of the nutritional fibre, important fatty acids, and 67% of the vitamin B3 available in the raw, unmilled type are lost during the milling and polishing processes, along with 80% of the vitamin B1, 90% of the vitamin B6, 50% of the manganese and phosphorus, and 60% of the iron.

Brown rice, milled rice, germ, bran, cracked, and husk are the by-products of milling rough rice (also known as paddy). These are all different from one another and have various uses. The pattern of use of these components, either directly or as derivatives, determines the degree of value addition in rice and rice products. Only the first three milling procedures, pre-cleaning, dehusking, and separation, are used for coloured rice varieties, leaving the bran and germ unaltered.

### Nutritional Values

#### White rice

When compared to maize, wheat, and potatoes, raw, long-grain white rice is a rich source of carbohydrates, calcium, iron, thiamine, pantothenic acid, folate, and vitamin E. Vitamins C, A, beta carotene, lutein, and zeaxanthin are not present. It has a notable lack of nutritional fibre as well.

#### Coloured

brown rice has not undergone as much polishing as white rice, it still has its bran layer, which is rich in vitamins, minerals, and fibre. The coloured rice types come in unpolished or semi-polished varieties. Black rice is particularly strong in protein, fat, and crude fibre, whereas red rice varieties are well recognised to be rich in iron and zinc. Anthocyanin pigments, which are known to have free radical scavenging and antioxidant properties as well as other health advantages, give red and black rice its colour. (Fig.2) Brown rice is very nutrient-dense. It has a lot of fibre and few calories. Additionally, it is an excellent source of manganese and a good supplier of magnesium, phosphorus, selenium, thiamine, niacin, and vitamin B6. Because vitamins are restricted to the bran and husk of the paddy, brown rice and rough rice are high in vitamins and minerals. Calcium, zinc, and iron levels are higher in rice bran and husk (Table 3).

Rice has a high glutamic and aspartic acid content but a low lysine content. Phytate, trypsin inhibitors, oryzacystatin, and haemagglutinin-lectin are the antinutritional components that are primarily abundant in bran [25].

#### Moisture

The shelf life of foods is significantly influenced by the moisture content [29]. Moisture affects the milling properties and flavour of cooked rice, according to Xheng and Lan [30]. The moisture content of different rice types depends on their genetic composition and the environmental conditions under which they are grown. Brown rice and milled rice have lower moisture contents than other rice kinds, as shown in Table 4, while the moisture level of red rice varieties varies from 9.3 to 12.94%.

### Protein

Rice's eating quality and nutritional value are influenced by protein, which is the next significant ingredient after starch. In India, 207.9 grammes of rice are consumed daily per person, providing around 24.1% of the recommended daily protein intake [2]. Due to its higher lysine concentration than wheat, corn, millet, or sorghum, rice has a well-balanced amino acid profile, making its protein superior to that of other cereal grains [36]. The highest among cereal proteins, rice protein has a lysine concentration of between 3.5 and 4.0%. The endosperm protein is composed of glutelin (alkali soluble), 5-8% prolamin (alcohol soluble), 15% albumin (water soluble), and globulin (salt soluble) [27].



Fig-2 There are some pigmented rice varieties of North India.

**Table 3** Vitamin and mineral content of rough rice and its milling fractions at 14% moisture [27,28].

coloured rice has a higher protein level than polished white rice. Chinese and Sri Lankan types contain more protein than Indian varieties (Table 4). Compared to endosperm proteins, rice bran proteins are higher in albumin. Albumin makes up 66% of the

| Rice fraction | Thiamine (mg) | Riboflavin (mg) | Niacin (mg) | $\alpha$ -Tocopherol (mg) | Calcium (mg) | Phosphorus (g) | Phytin (g) | Iron (mg) | Zinc (mg) |
|---------------|---------------|-----------------|-------------|---------------------------|--------------|----------------|------------|-----------|-----------|
| Rough rice    | 0.26–0.33     | 0.06–0.11       | 2.9–5.6     | 0.90–2.00                 | 10.0–80.0    | 0.17–0.39      | 0.18–0.21  | 1.4–6.0   | 1.7–3.1   |
| Brown rice    | 0.29–0.61     | 0.04–0.14       | 3.5–5.3     | 0.90–2.50                 | 10.0–50.0    | 0.17–0.43      | 0.13–0.27  | 0.2–5.2   | 0.6–2.8   |
| Milled rice   | 0.02–0.11     | 0.02–0.06       | 1.3–2.4     | 0.075–0.30                | 10.0–30.0    | 0.08–0.15      | 0.02–0.07  | 0.2–2.8   | 0.6–2.3   |
| Rice bran     | 1.20–2.40     | 0.18–0.43       | 26.7–49.9   | 2.60–13.3                 | 30.0–120.0   | 1.1–2.5        | 0.9–2.2    | 8.6–43.0  | 4.3–25.8  |
| Rice hull     | 0.09–0.21     | 0.05–0.07       | 1.6–4.2     | 0                         | 60.0–130.0   | 0.03–0.07      | 0          | 3.9–9.5   | 0.9–4.0   |

aleurone protein bodies, globulin makes up 7%, and prolamin and glutelin make up 27% [37].

### Fat

Linoleic acid and other important fatty acids are found in significant amounts in the fat found in rice. Cholesterol is absent from the rice [36]. The rice bran (20%, dry basis) is where the majority of the lipids or fats are found in rice. In the aleurone layer and bran, it can be found as lipid bodies. Linoleic, oleic, and palmitic acids are the three main fatty acids found in the lipid bodies' core [38, 39]. The monoacyl lipids (fatty acids and lysophosphatides) in rice's starch lipids are complexed with amylose [40]. Red rice varieties from Sri Lanka and India have roughly 1% fat, according to the amount of fat present in different fractions of rice and red rice, while the China red rice has almost doubled this value (Table 4).

**Table 4** Proximate composition of rice based on its milling fractions and coloured varieties

| Rice                                   | Moisture     | Protein (g) | Fat (g)      | Crude fibre (g) | Crude ash (g) | Carbohydrates (g) | References   |
|--|--------------|-------------|--------------|-----------------|---------------|-------------------|--------------|
| Rough rice                             | 14.0         | 5.8–7.7     | 1.5–2.3      | 7.2–10.4        | 2.9–5.2       | 64.0–73.0         | [25, 27, 31] |
| Brown rice                             | 7.1–11.6     | 5.9–11.0    | 1.6–2.8      | 0.22–0.95       | 0.43–2.34     | 71.31–84.75       | [4]          |
| Raw hand pound rice                    | 13.3         | 7.5         | 1.0          | 0.6             | 0.9           | 76.7              | [32]         |
| Milled rice, raw                       | 9.93 ± 0.75  | 9.16 ± 0.75 | 1.24 ± 0.08  | 1.04 ± 0.18     | 4.43 ± 0.54   | 74.80 ± 0.85      | [33]         |
| Parboiled rice                         | 10.09 ± 0.43 | 7.81 ± 0.63 | 0.55 ± 0.08  | 0.65 ± 0.08     | 3.74 ± 0.36   | 77.16 ± 0.76      | [33]         |
| White rice (polished)                  | 7.01–11.2    | 5.8–7.7     | 0.5–2.3      | 0.01–0.78       | 0.12–1.22     | 76.8–86.56        | [4]          |
| Rice bran                              | 14.0         | 11.3–14.9   | 15.0–19.7    | 7.0–11.4        | 6.6–9.9       | 34.0–62.0         | [27, 28, 31] |
| Rice hull                              | 14.0         | 2.0–2.8     | 0.3–0.8      | 34.5–45.9       | 13.2–21.0     | 22.0–34.0         |              |
| Red rice                               | 9.3–13.1     | 7.16–10.85  | 1.15–3.19    | 0.28–0.61       | 0.82–1.5      | 70.75–81.29       | [34]         |
| Sri Lanka red rice                     | 12.94 ± 0.03 | 9.63 ± 0.04 | 1.15 ± 0.03  | 2.82 ± 0.55     | 0.82 ± 0.14   | 75.45 ± 0.09      |              |
| China red rice                         | 11.90 ± 0.20 | 9.72 ± 0.04 | 2.35 ± 0.03  | 2.52 ± 0.24     | 1.37 ± 0.02   | 74.66 ± 0.17      |              |
| Chak-hao amubi (Manipur black rice)    | 11.90 ± 0.20 | 8.8 ± 0.05  | 1.0 ± 0.07   | 0.3 ± 0.06      | 0.5 ± 0.07    | 78.0 ± 0.03       | [34]         |
| Maappillai Samba (Tamil Nadu red rice) | 10.3 ± 0.73  | 8.16 ± 0.45 | 0.918 ± 0.13 | 2.5 ± 0.28      | 2.26 ± 0.72   | 75.86 ± 2.31      | [35]         |

### Fibre

Dietary fibre increases the volume of faeces, which has a laxative effect on the digestive system. For well-milled rice, the fibre level ranges from 0.5 to 1.0% [41]. In rice, arabinoxylans and -d-glucan make up the majority of the soluble dietary fibre. In addition, soluble dietary fibre contains rhamnose, xylose, mannose, galactose, and glucose. Cellulose, hemicellulose, insoluble -glucan, and arabinoxylans make up insoluble dietary fibre. The rice cultivar, level of milling, and water solubility all affect the quantity and amount of non-starch polysaccharide [42]. Chak-hao amubi (Manipur black rice), a variety of red rice, contains the lowest amount of crude fibre of all the red rice variants (Table 4).

### Ash

Varied rice cultivars may have different ash contents for a variety of reasons, including genetics or soil mineral concentration [43]. Red rice has a two to three times higher zinc and iron content than white rice [44]. Rice contains calcium, magnesium, iron, and zinc, which are the most frequently occurring minerals (Table 3). The type of rice and degree of milling, which entirely or partially eliminates the bran layer, aleurone layer, and embryo, affect the proximate composition of rice and its fractions. As a result, the nutritional value of the different rice fractions from the same rice variety varies. The changes can be seen in the grain's content of nutrients, fibre, and lipids.

### Phytochemical composition

Phytochemicals are non-nutritive plant compounds that have a protective or disease-preventing property. The pericarp and bran of the rice kernel are where the phytochemical substances are primarily stored. They provide a wide range of advantageous biological functions in addition to preventing oxidative damage to meals. Carotenoids, phenolics, alkaloids, nitrogen, and organo-sulfur containing compounds are the subgroups of phytochemicals found in rice.

The subgroups of phenolic substances include phenolic acids, flavonoids, coumarins, and tannins. Anthocyanins, the main pigment in charge of giving red and black rice their colours, are a type of flavonoid. Red rice from Tamil Nadu called Maappillai Samba has more anthocyanin and total polyphenolic chemicals than Sri Lankan red rice, Chinese red rice, and Manipur black rice variants combined

**Table 5** Total polyphenolic content and total anthocyanin content of pigmented rice varieties

| Varieties                                | Total phenolic content (mg 100–1 g) | Total anthocyanin content (mg cyanidin-3-glucoside equivalent 100–1 g) | Reference |
|--|-------------------------------------|--|-----------|
| Sri Lanka red rice                       | 118.47 ± 11.52                      | 0.35 ± 0.02  | [34]      |
| China red rice                           | 253.34 ± 5.14                       | 1.00 ± 0.01  |           |
| Chak-hao amubi (Manipur black rice)      | 579.00                              | 1.81   | [35]      |
| Maappillai Samba (Tamil Nadu black rice) | 294.71 ± 33.9                       | 6.52 ± 2.73  |           |

The phytochemical components found in red, purple, and black rice are present in higher concentrations than those in non-pigmented cereal grains. More research is being done on phytochemicals since they can be easily taken into the body and can be broken down by digestive enzymes and gut microbiota, such as cell wall-bound phenolics and flavonoids [45].

Anthocyanins found in coloured rice bran have anti-diabetic and reductase enzyme-inhibitory properties [46]. The reductase inhibitors are used to treat benign prostatic hyperplasia and alleviate symptoms related to the urinary tract since they have antiandrogen properties. The -sitosterol found in Maappillai Samba (Fig. 2g) lowers cholesterol, boosts fertility, and even treats colon cancer. Additionally, this variety's stigmaterol serves as a precursor in the synthesis of semi-synthetic progesterone [11].

Garudan Samba It contains 9,12-octadecadienoic acid (Z, Z), which may have anti-arthritic, anti-inflammatory, hepatoprotective, 5-alpha-reductase inhibitory, anti-histaminic, anti-coronary, and anti-androgenic properties. This substance is found in garudan samba. It also includes a number of additional bioactive substances in addition to these [47].

In addition to having antimicrobial properties and being found in red Kavuni (Fig. 2a), 3-hydroxy-4-methoxy benzoic acid is also employed as a precursor in the manufacture of morphine. 3-Cyclohexene-1-methanol and,4-trimethyl- Fatty acid esters and fatty acids such dodecanoic acid, ethyl ester (a lauric acid ester), and octadecanoic acid are also present in addition to these molecules. Octadecanoic acid and ethyl esters are two of these bioactive substances that raise levels of low-density lipoprotein (LDL) cholesterol in the body [48].

### Health benefits

People choose various types of rice depending on the flavours, culinary requirements, availability, and potential health benefits. Rice has the capacity to deliver quick and immediate energy. Among other minerals, brown and red rice are excellent providers of fibre, B vitamins, calcium, zinc, iron, manganese, selenium, and magnesium. A class of phytochemicals known as anthocyanin, which are also present in deeply purple or crimson fruits and vegetables, give the red and black rice variety its vibrant colour.

### Diabetes mellitus

Brown rice releases sugars more gradually than white polished rice, which helps to stabilise blood sugar levels over time. Brown rice releases sugars more gradually than white polished rice, which helps to stabilise blood sugar levels over time. Because of this quality, it is a preferable choice for those with diabetes mellitus. Additionally, research from Asia has linked white rice consumption to an increased risk of type 2 diabetes. By enclosing the food, preventing the action of hydrolytic enzymes in the small intestine on food, and raising the viscosity of food in the intestine, dietary fibres decrease the absorption of carbohydrates [49]. This is essential for lowering food's GI and lowering the risk of type 2 diabetes [50]. Red rice's proanthocyanidin content protects against type 2 diabetes [51]. Similar to this, black rice's anthocyanin content is reported to have a hypoglycemic effect [52].

### Cancer

Brown rice contains high levels of selenium and manganese, both of which are essential in the fight against free radicals, a key cancer-causing factor. These components and the high dietary fibre content of brown rice are linked to a lower risk of cancer. The consumption of whole grains, such as brown rice, has also been linked in studies to lower rates of colon cancer. This may be due to its high fibre content, which binds to carcinogens and toxins and aids in their removal from the body while also preventing them from adhering to the cells in the colon. Red rice contains proanthocyanins, which control the inflammatory response and offer modest cancer protection[51]. According to epidemiological, in vivo animal and human research, anthocyanins, which are rich in black rice, exhibit anti-carcinogenic characteristics [53].

### Cardiovascular disease

The consumption of brown rice may reduce the chance of developing the metabolic syndrome, which is a strong indicator of cardiovascular disease. Magnesium in red rice lowers the risk of heart attacks [54]. In rat models, anthocyanin-rich extracts from black rice reduced a number of high-fat diet-induced risk factors for cardiovascular disease [55].

### Cholesterol

Naturally occurring bran oil found in brown rice aids in lowering LDL cholesterol. Black rice consumption has been reported to eliminate reactive Lower cholesterol levels are caused by oxygen species (ROS) like lipid peroxide and superoxide anion radicals, which due to the presence of substances like anthocyanins, Phytic acid, flavonoids, vitamin E, and  $\gamma$ -oryzanol are polyphenolic chemicals.[56,57]. Proanthocyanidins in red rice offered protection from cardiovascular disease by modifying inflammatory responses [51].

These studies clearly show that whole grains help reduce arterial plaque buildup, which lowers the risk of getting heart disease.

### Hypertension

Red and brown rice both have more magnesium than white rice. Magnesium is a significant mineral that is essential for maintaining healthy blood pressure and sodium levels in the body [54].

### Obesity

Brown, red, and black rice are examples of rice varieties that are high in fibre and can support good bowel and metabolic function. Red rice contains anthocyanins that may be useful for controlling weight [54].

### Allergy

Although goods from other plant sources, like soy and peanuts, and products from animals, like eggs and milk, are good sources of protein, they may also cause allergies when taken. Rice protein is hypoallergenic. Since rice protein is hypoallergenic, it offers a solution to this issue. Additionally, red rice's anthocyanins have the ability to lessen allergic symptoms [54].

### Applications of coloured rice in medicine

Few variations of the many different forms of rice are utilised as medicines. Since each type of rice has distinctive qualities, more than one variety can be used to treat different diseases. Due to their unique features and traits, many distinct rice cultivars are used in the treatment of diseases. Ayurvedic practitioners claim that rice brings the body's humours into balance. By removing harmful metabolites, rice strengthens, revitalises, and energises the body, controls blood pressure, and protects against skin illnesses and early ageing. Rakthasali (a type of red rice) is effective in taming unbalanced bodily humours, helpful for fevers and ulcers, enhances vision, voice, skin health, and fertility [58–61]. Sali, Sashtika, and Nivara rice are all used in Ayurveda to treat bleeding from haemorrhoids (piles), burns, and fractures. Nivara rice is also used to make weaning food for underweight babies, treat cervical spondylitis, paralysis, rheumatoid arthritis, neuromuscular disorders, psoriasis, skin lesions, and stomach ulcers. Diseases can be controlled by using rice water that has been made by soaking rice in water or boiling rice in extra water. Various rice types are

utilised in Ayurvedic remedies to treat conditions like vaginal and seminal discharges, diarrhoea, constipation, and dysentery [58]. These rice varieties include Mahagandhak ras, Kamdudha ras, Sutsekhar ras, Amritanav ras, Swarnmalti ras, Pradraripu ras, Laghumai ras, Dugh. It is well known that red rice varieties can be used to cure conditions like diarrhoea, vomiting, fever, haemorrhage, chest pain, wounds, and burns [63]. In Himachal Pradesh, matali and lal dhan are used to treat high blood pressure and fever. Leucorrhoea and complications from abortion are treated using a red rice variety from the Himachal Pradesh and Uttar Pradesh hills called Kafalya [64]. While Neelam Samba from Tamil Nadu is utilised for breastfeeding women, Kari Kagga and Atikaya from Karnataka are used for coolness and as tonics [65]. The natives eat Kuruvi Kar because it is drought-resistant and has positive health effects [66]. Deranged humour can be effectively controlled by Raktasali [60, 61]. It was also thought to be a successful treatment for conditions including fevers and ulcers. Additionally, it is thought to be antitoxic, diuretic, spermatophytic, cosmetic, and tonic, as well as improving eyesight and voice [59].

### Traditional cuisine's significance

Pigmented rice is consumed as a whole grain since ayurvedic texts mention it as a nutritive diet and medication. Pigmented rice cultivars from Jharkhand and Chattisgarh, such as Bhama, Danigora, Karhani, Kalmdani, Ramdi, Muru, Hindmauri, and Punaigora, are high in nutrients and give people all day long energy and satiety [67, 68]. It is traditionally cook and eat a variety of meals, including pongal, puttu, adai, appam, idli, dosai, idiyappam, adirasam, kozhukattai, modakam, payasam, semiya, uppuma, flaked rice, and puffed rice, among others. Prior to milling, paddy is parboiled in Tamil Nadu and Kerala. The endosperm can more easily absorb vitamins and minerals from the bran and aleurone layer because to this hydrothermal action [69]. In the South Indian diet, rice replaces wheat as the main cereal, whereas in the North Indian diet, wheat occupies the top spot. Breakfast dishes include dosai, idli, pongal, appam, semiya, uppuma, kichadi, and idiyappam, as well as a large variety of chutney. Breakfast is also served, and the specialty meal called puttu consisting of rice is cooked. South Indians typically eat cooked parboiled rice, poriyal, eggs, meat, rasam, pappad, moore (buttermilk) or curd, and/or dessert, payasam, for lunch. Typically, idli, dosai, idiappam, cooked rice, and curries make up the supper.

Biryani, pulao, fried rice, curd rice, tamarind rice, sambar rice, jeera rice, lemon rice, coconut rice, and many other cuisines are also made from rice. Kangsoi are also created in Manipur using the coloured rice. A speciality meal called fish rice is made in Manipur using koliyal and fish (Kadai Kazhuthaan) [47] Black Gunja is used to make flatbread and chapatti, while sticky rice is utilised to make puttu, a South Indian dish [70]. The many coloured rice varieties are also used to make a number of items, including biscuits and murruku, a type of South Indian food.

Additionally, a significant portion of festivals observed in India. Harvest celebrations are observed with a variety of scrumptious foods produced with recently harvested paddy. Green, uncooked rice is used to make wadi chawal in Punjab. fried rice balls in Assam; gramme, daal wadi prepared and eaten are ghila pitha; in Traditional Bengali foods are produced in West Bengal. The most popular one is homemade sweets prepared from rice pitha and karpursal or banapuli with freshly harvested rice and jaggery. Basmati rice is also used to produce Bengali paish.

Thondi, Matta, Paal Thondi, Kuruva, Chitteni, and Chettadi are some of the parboiled coloured rice varieties that are popular in Bihar. It is known as the "Basmati of North India" and is used to make biryani. Seeraga Samba is an aromatic rice type that is frequently consumed in Gujrat and Madhya Pradesh. In a similar vein, the aroma of Jatu from the Kulu Valley, Ambemohar from Maharashtra, Dubraj from Madhya Pradesh, Joha from Assam, Kamod from Gujarat, Badshah bhog from West Bengal and Odisha, Radhunipagla from West Bengal, Katrini and Kalanamak from Uttar Pradesh and Bihar, Gandha samba from Kerala, Kalajira from Odisha, and Chakha.

Today, the spotlight is on the increased production of these traditional varieties, promoting the consumption among the younger generation and production of nutritious and novel value-added products from coloured rice.

### Conclusion

Although traditional pigmented rice varieties are grown in India and are widely used by communities and practitioners of traditional medicine as a part of their cultural heritage, the functional effects and health benefits of these varieties in terms of current scientific methodology are few and far between. Most people are still unaware of these types' positive traits because there isn't enough information available about them. Therefore, in order to capitalise on their health benefits, thorough research on these local coloured variants by the stakeholders must be encouraged so that consumers can access them as a part of the daily diet or speciality functional foods.

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