

RICE GRAIN, A RICH SOURCE OF NATURAL BIOACTIVE COMPOUNDS

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Rice, which is the most cultivated crop worldwide, is mainly grown as a staple food. Thousands of rice varieties are cultivated; however, their nutritional and medicinal values have not been thoroughly investigated. Rice grain is rich in various bioactive compounds such as phenolic compounds, phytosterols, gallic acid, polycosanol, oryzanol, tocopherol, tocotrienols and ferulic acid. Furthermore, several types of rice and their byproducts are effective for treatment of a number of deteriorating diseases including dysentery, cancer, diabetes and heart disease. Therefore, the present review was conducted to highlight different varieties of rice and their medicinal potentials along with the nutritional composition, bioactive compounds and nutraceutical potentials of rice grain. The integral information combining rice natural bioactive compounds with disease treatment provided herein will be useful for development of drugs for the treatment of various diseases using the rice-derived bioactive compounds.

Keywords: *Oryza sativa*, nutraceutical, anthocyanins, antioxidant, phenolic compounds

INTRODUCTION

Rice crop from a semi-aquatic annual grass plant, is an essential food for billions of people worldwide, as well as a symbol of cultural identity and global unity. It is the third leading food crop beside wheat and corn. Since various nutrients including minerals and vitamins are present in rice, and due to its calorie content, around 50% of the earth's population uses rice as a principal food source (USDA, 2013). A total of 24 species of rice belonging to the genus *Oryza* consisting of about 120,000 varieties are recognized throughout the world. Among these species, only two species *Oryza sativa* and *O. glaberrima* are cultivated for food purpose. Varieties found in Asia, America and Europe belong to the species *O. sativa* ($2n=24$), while those found in West Africa belong to the species *O. glaberrima* ($2n = 24$) (Lin *et al.*, 2015).

In addition to its importance as a staple food, interest in its medicinal potential and various health benefits has recently attracted a great deal of attention. Medicinal rice is not only found on the Indian subcontinent, but also in China, where medicinally important rice varieties have long been used in traditional system of medicine (Rahman *et al.*, 2006; Umadevi *et al.*, 2012). Although the medicinal uses of rice have not been scientifically validated, it has been used in traditional medicinal treatments in many countries (Umadevi *et al.*, 2012). The main rice products produced from grains of pigmented rice such as red, black, and brown rice, along with rice bran oil are used for medicinal purposes.

Various experimental results have proved that potential of rice products for treatment of different diseases such as heart disease, diabetes, and kidney stones etc. together with promising antioxidant and anti-cancer potential. Rice

comprises several phytochemicals, which are described to have health encouraging abilities, counting anticancer and antioxidant properties (Min *et al.*, 2012; Prajapati and Patel, 2013; Chung *et al.*, 2015; Somintara *et al.*, 2016). The medicinal properties of rice varies with the different types and varieties (Rahman, 2007; Bhat and Riar, 2015). Rice bran and husks that are rich in fiber, vitamin E, minerals and other bioactive compounds and phenolics are known to possess medicinal properties (Gul *et al.*, 2015), such as lowering cholesterol levels in the blood, absorbing fats in the gut, and help in the digestion process.

Nevertheless, there is scant information available regarding the medicinal potential of different rice varieties and the nature of bioactive compounds responsible for its medicinal properties. Therefore, the present review highlights the nutritional compositions of various varieties of rice with medicinal potential and types of bioactive compounds present in rice grains.

Different Varieties of Rice with Medicinal Properties:

Brown rice: Brown rice is whole grain rice with a mild flavor. It is more nutritious than the white rice, but goes rotten quickly because the bran and germ, which are removed to make white rice, contain fats that can spoil (Rosniyana *et al.*, 2006; Asyifah *et al.*, 2012). This type of rice is highly rich in fiber, minerals and vitamins (calcium, iron, thiamin, niacin, riboflavin), while it also contains proteins and small amounts of fat (Meng *et al.*, 2005). Scientists reported that brown rice comprises large quantities of insoluble fiber, to defend the human body against number of cancers. Furthermore brown rice are valuable food sources for the persons suffering from hypertension because of its low sodium content, besides a reasonable source of protein comprising total eight amino

acids (Umadevi *et al.*, 2012; Bhat and Riar, 2015). Brown rice is the great source of γ -oryzanol, and is an essential source of bioactive compounds and nutraceuticals with various prospective health conditions (Hongisbong *et al.*, 2016).

Black rice: Black rice, which is otherwise known as purple rice, is deep black in color and a rich source of natural antioxidants. The outer layer of this rice contains antioxidant-rich bran, whereas the purple and reddish pigment of this rice gives it a black appearance due to the presence of anthocyanins. This rice has a mild taste, and contains a comparable amount of fiber as brown rice (Ichikawa *et al.*, 2001). In China, people believed that the black rice has body strengthening potential and other pharmaceutical properties (Hu *et al.*, 2003); therefore, it is also known as "drug rice" or "blood strengthening rice". Anthocyanin is the major pigment of black rice and it possess a number of biological properties including anti-carcinogenic, anti-inflammatory and anti-oxidative activities (Min *et al.*, 2011; Chen *et al.*, 2012; Hayashi and Yanase, 2016).

Red rice: Red rice, a low-yield rice variety commonly known as weedy rice, appears red owing to the content of anthocyanins in its husk (Oki *et al.*, 2002). This type of rice has a nutty flavor and a high nutritional value if the germ is left intact (Walter *et al.*, 2013). Proanthocyanidins are the key pigments of red rice which are made up of flavan-3-ol units, rich in micronutrients and vitamins and the bioactive compounds exhibit useful natural properties, as well as great anti-oxidative activity (Yawadio *et al.*, 2007; Min *et al.*, 2011; Chen *et al.*, 2012; Hayashi and Yanase, 2016). As a noble source of bioactive phytochemicals, including γ -oryzanol, phenolic compounds, tocopherols and tocotrienols red rice is one of the utmost nutritious rice (Zeng *et al.*, 2013; Kaur *et al.*, 2015).

Red yeast rice: Red yeast rice is the fermented product of rice that is fermented with *Monascus purpureus* yeast. Red yeast rice is used as medicine. Red yeast rice extensively reduces total triacylglycerols and cholesterol and provides a novel, food-based approach to lower the level of cholesterol in the body (Lu *et al.*, 2008). Red yeast rice has been used since long in China and other Asian countries as a source of food preservative, spice and ingredient in rice wine and medicine (Ma *et al.*, 2000; Doughari, 2015). Red yeast rice, has been used for 1200 years as a remedy for problems associated with circulation and digestion. It is an herbal medicine and a traditional Chinese food prepared by fermenting rice with *Monascus purpureus*. Red yeast rice contains a variety of compounds recognized as monacolins. It was found to be the best effective inhibitor of cholesterol synthesis (McCarty *et al.*, 2015; Bunnony *et al.*, 2015).

Parboiled rice: Parboiled rice is processed differently from other types of rice, but the resulting grain is cooked and served using the same methods as for white or brown rice. However, due to its special processing, parboiled rice is a better source of calcium, potassium, fiber and vitamin B-6 than any other

regular white rice varieties (Heinemann *et al.*, 2005; Roy *et al.*, 2011). For enhancement of quality of rice parboiling is an applied technique. Parboiling considerably changed the properties of rice starch in addition as a whole to the kernel of rice (Dutta *et al.*, 2015).

Basmati rice: Basmati rice is an aromatic rice with long grain that has good aroma, a fine surface and a crazy flavor that is primarily grown in the pristine foothills of the Himalayas (Devindra and Longvah, 2011). Additionally, the fiber content of brown basmati rice is high, while its fat content is very low and it contains moderate thiamine and niacin contents, all of which play a vital role in the breakdown of energy (Devindra and Longvah, 2011). Aromatic brown basmati rice comprises of 20% extra fiber than other varieties of brown rice (Bhat and Riar, 2015). This brown basmati rice inhibits the development of cancerous cells in the human body (Bhat and Riar, 2015).

Pigmented rice: Pigmented rice, or colored rice, is well-known by the rice grain having a red brown or dark purple color in its covering layers. The pigments, which are located in the aleuronic layer of rice grain, have been reported to consist of a mixture of anthocyanin compounds with a number of biological activities (Yawadio *et al.*, 2007; Chen *et al.*, 2012; Suttiarporn *et al.*, 2015; Hayashi and Yanase, 2016; Huang and Lai, 2016).

White rice: This rice is white in color owing to removal of the hull and bran during milling. White rice has fewer nutrients than pigmented rice, but is a common source of starches, syrups and flour (Abbas *et al.*, 2011). The beneficial health components of white rice, comprises phenolic compounds, sterols, γ -oryzanol, tocotrienols and tocopherols which subsists particularly in the outer layer such as pericarp and aleurone of rice grains (Huang and Lai, 2016).

Jasmine rice: Jasmine rice, which is more popularly known as "Thai fragrant rice", originated from Thailand. Jasmine rice is long grain rice that gives off a delicate jasmine aroma when cooked (Payakapol *et al.*, 2011). Jasmine rice contains omega-3 fatty acids, which can maintain the brain and prevent Alzheimer's disease (Payakapol *et al.*, 2011).

Glutinous rice: Glutinous rice is known as sweet rice. Consumption of sticky rice can also strengthen the lung energy and aid in treatment and prevention of excessive perspiration (Roder *et al.*, 1996). Thai glutinous rice after fermentation with *Monascus purpureus* CMU 002U, have been reported to reduce the serum cholesterol and hepatic cholesterol levels of the diet-induced hypercholesterolemic in rats (Bunnony *et al.*, 2015).

Other parts of rice grain with medicinal potential: Rice bran is the brownish hard outer layer of rice that is removed in fine grain form during de-husking and milling. It is a rich source of essential fatty acids, dietary fiber, vitamins, minerals, and other sterols (Hernandez *et al.*, 2000; Gul *et al.*, 2015). Rice bran is a collection of micronutrients that includes phytoosterols, tocotrienol, tocopherol, γ -oryzanol, beta-glucan,

pectin and gum (Nagendra *et al.*, 2011). Rice bran oil is rich in natural antioxidants which helps in decreasing the possibility of chronic diseases (Thanonkaewa *et al.*, 2012). Numerous investigations specified that rice bran is highly rich in γ -oryzanol which is a combination of triterpene alcohols, sterols and ferulic acid esters (Gul *et al.*, 2015).

Nutritional Composition of Rice: Rice is rich in carbohydrates, vitamins and minerals such as calcium, iron, niacin, thiamine, riboflavin, vitamin D and fiber and is highly nutritional in nature (Table 1) (Halvorsen *et al.*, 2002; Anjum *et al.*, 2007; Umadevi *et al.*, 2012; Kale *et al.*, 2015). Moreover, it does not contain any fat, cholesterol or gluten and the nutritional value of husked rice is greater than that of polished rice or milled rice (Rahman *et al.*, 2006). The major product of milled rice is approximately 700 g kg⁻¹ rice (endosperm), 200 g kg⁻¹ rice husk, 80 g kg⁻¹ rice bran and 20 g kg⁻¹ rice germ (Nagendra *et al.*, 2011).

Table 1. Average nutrient content in different rice varieties.

Nutrient	Content (g kg ⁻¹ of dry grain weight)	Reference
Carbohydrate	700-750	Rahman <i>et al.</i> , 2006; Anjum <i>et al.</i> , 2007
Protein	80-100	Halvorsen <i>et al.</i> , 2002; Rahman <i>et al.</i> , 2006; Anjum <i>et al.</i> , 2007
Fat	5-10	Halvorsen <i>et al.</i> , 2002; Rahman <i>et al.</i> , 2006
Fibre	5-10	Halvorsen <i>et al.</i> , 2002; Rahman <i>et al.</i> , 2006
Vitamins	100-150	Halvorsen <i>et al.</i> , 2002; Rahman <i>et al.</i> , 2006
Minerals	10	Rahman <i>et al.</i> , 2006
Antioxidant concentration	0.07	Rahman, 2007

Much of the nutrition of rice is lost during milling and polishing. Rahman *et al.* (2006) have reported that, polishing of rice grain resulted in loss of 290 g kg⁻¹ of the protein, 790 g kg⁻¹ of the fat, 840 g kg⁻¹ of the calcium oxide and 670 g kg⁻¹ of the iron. Approximately, rice whole grains contain 1030 mg kg⁻¹ phosphorus, 1500 mg kg⁻¹ potassium, 350 mg kg⁻¹ magnesium, 60 mg kg⁻¹ calcium, 20 mg kg⁻¹ sodium, 17 mg kg⁻¹ zinc, 12 mg kg⁻¹ iron, 9 mg kg⁻¹ manganese and 2 mg kg⁻¹ copper as evident from the published literature (Jideani, 2012). Jeon *et al.* (2006), have reported that the approximate mineral contents of the dry husks of rice are 380 g kg⁻¹ cellulose, 200 g kg⁻¹ hemicellulose and 220 g kg⁻¹ lignin and the dry rice bran fiber contains 300 g kg⁻¹ cellulose, 200 g kg⁻¹

hemicellulose and 200 g kg⁻¹ of lignin. Apart from this, the oil from rice bran contains vitamin E and minerals in higher quantity.

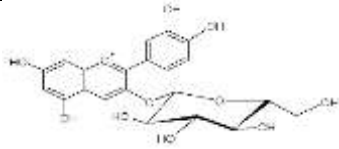
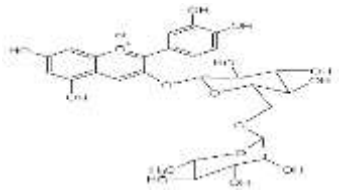
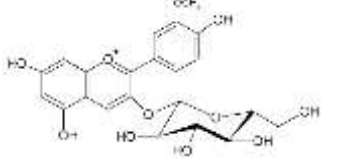
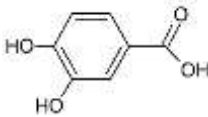
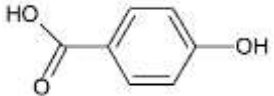
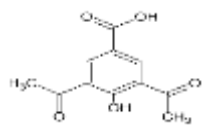
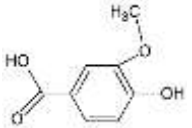
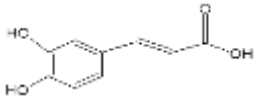
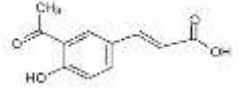
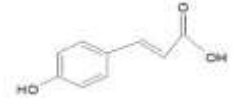
Bioactive Compounds in different Varieties of Rice: Rice is a rich source of a variety of natural bioactive compounds, including trace elements, carotenoids, phytic acid, vitamin E, hydroxyl vanillic acid, folate, cinnamic acid, polyphenols, gallic acid, minerals, ferulic acid, lignin, alkyl resorcinols and ρ -coumaric acids. These are primarily polyphenolic in nature, and ferulic acid is the most potent (Jeon *et al.*, 2006; Goufo and Trindade, 2014; Kim *et al.*, 2015). In rice, the foremost oryzanol constituents are ferulate, campesterol ferulate, sitosterol ferulate, 24-methylene cycloartanyl and cycloartenyl ferulate (Ekasit and Jiraporn, 2013). Some of the predominant bioactive compounds present in different rice varieties are discussed below (Table 2; Fig. 1).

Phenolic compounds: In plants, phenolic compounds (polyphenols) are broadly distributed, and some of them have been identified as natural antioxidants (Walter *et al.*, 2013). Phenolic compounds can be classified into two groups, flavonoids and non-flavonoids. In rice, these compounds are present in free forms, bound with sugars, fatty acids or as proteins. The levels of phenolics in rice are correlated with its UV-B tolerance (Zhou *et al.*, 2004). These compounds varies according to their simple structure such as phenolic acids, to highly polymerized complex structures, such as the tannins (Zhou *et al.*, 2004).

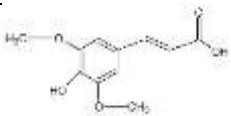
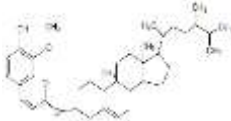
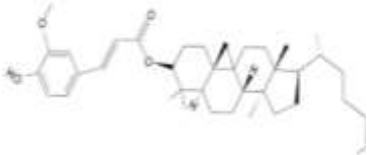
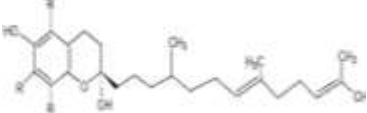
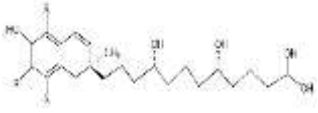
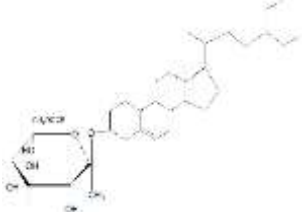


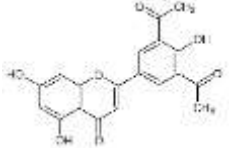
A number of phenolic compounds have been documented in different rice varieties (Walter and Marchesan, 2011; Goffman and Bergman, 2004; Massaretto *et al.*, 2011; Setyaningsih *et al.*, 2016). The major phenolic compounds found in rice grains with light brown pericarp color are phenolic acids, typically the ferulic and coumaric acids (Zhou *et al.*, 2004). Other identified compounds includes protocatechuic acid and sinapic acid (Tian *et al.*, 2004), chlorogenic acid, hydroxybenzoic acid (Tian *et al.*, 2005), caffeic acid, gallic acid, syringic acid, tricinn and, vanillic acid (Hudson *et al.*, 2000) and the esters like 6'-O-(E)-feruloylsucrose and 6'-O-(E)-sinapoylsucrose (Walter and Marchesan, 2011). Red and purple pigmented flours, within each rice variety, had greater level of total phenolic compounds (Pongjanta *et al.*, 2016).

Polyphenols have several biological functions including antioxidant, anti-inflammatory and anti-cancer activities, which are beneficial to the human health (Walter and Marchesan, 2011; Jideani, 2012; Setyaningsih *et al.*, 2016). Rice contains about 100 different types of antioxidants, including γ -oryzanol, tocopherol and tocotrienol, which are the most influential flavonoids (Dykes and Rooney, 2007). Rice bran oil helps to reduce the levels of cholesterol in blood vessels.

Table 2. List of compounds, chemical structures and their bioactive potential present in rice grain.

Name of compounds	Part of rice	Chemical structure	Bioactive potential	References
Cyanidin 3-glucoside	Rice grain		Antioxidant Anticancer Anti-inflammatory	Chen <i>et al.</i> , 2005; Abdel <i>et al.</i> , 2006; Dykes and Rooney, 2007; Xia <i>et al.</i> , 2006; Daiponmaka <i>et al.</i> , 2010
Cyanidin 3-rutinoside	Rice grain		Antioxidant	Abdel <i>et al.</i> , 2006
Peonidin-3-glucoside	Rice grain		Antioxidant Anticancer	Mazza and Gao, 2005; Chen <i>et al.</i> , 2005; Dykes and Rooney, 2007
Protocatechuic acid	Rice grain and bran		Antioxidant Tyrosinase activity	Miyazawa <i>et al.</i> , 2003; Mattila <i>et al.</i> , 2005
<i>p</i> -Hydroxybenzoic acid	Rice grain		Antioxidant Antimicrobial	Cho <i>et al.</i> , 2004; Kim <i>et al.</i> , 2006
Syringic acid	Rice grain		Antioxidant	McDonough <i>et al.</i> , 2000; Zhou <i>et al.</i> , 2004
Vanillic acid	Rice grain		Antioxidant	Zhou <i>et al.</i> , 2004
Caffeic acid	Rice grain		Antioxidant	Manach <i>et al.</i> , 2004; Dimitrios, 2006
Ferulic acid	Rice grain		Antioxidant Anticancer	Yanishlieva-Maslarova and Heinonen, 2001; Henderson <i>et al.</i> , 2012
<i>p</i> -Coumaric acid	Rice grain		Antioxidant	Rao and Muralikrishna, 2000

Bioactive compounds in rice

Name of compounds	Part of rice	Chemical structure	Bioactive potential	References
Sinapic acid	Rice grain		Antioxidant	Mazza and Gao, 2005
Campesterol ferulate	Rice bran		Antioxidant	Berger <i>et al.</i> , 2005; Lai <i>et al.</i> , 2009; Saikia and Deka, 2011
Cycloartenyl ferulate	Rice bran		Antioxidant	Chen and Bergman, 2005; Kim, 2005; Berger <i>et al.</i> , 2005; Saikia and Deka, 2011
Tocotrienol	Rice grain and bran		Anticancer	Miyazawa <i>et al.</i> , 2008; Lai, Li, Lu, & Chen, 2009; Kannappan <i>et al.</i> , 2010
Tocopherol	Rice bran		Antioxidant	Lai <i>et al.</i> , 2009
Acylated steryl β-glucoside	Rice grain		Antioxidant Antidiabetic	Usuki <i>et al.</i> , 2011; Imam <i>et al.</i> , 2012
γ-aminobutyric acid	Rice grain		Antidiabetic	Imam <i>et al.</i> , 2012
β-sitosterol	Rice bran		Anticancer	Henderson <i>et al.</i> , 2012
Tricin	Rice bran		Anticancer	Henderson <i>et al.</i> , 2012

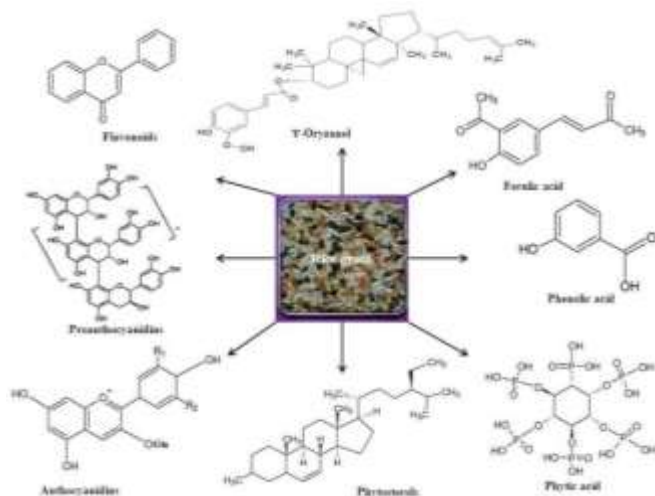


Figure 1. Various bioactive compounds present in rice grain.

Ferulic acid: An important by-product of the refining of raw rice bran oil is ferulic acid, a polyphenolic compound with antioxidative and antibacterial properties (Ryan *et al.*, 2011; Kumar and Pruthi, 2014). This material is formed from the metabolism of two amino acids, phenylalanine and tyrosine, and mostly found in the cells or seed walls of rice. Ferulic acid has strong antioxidant potential that protects skin cells from light or radiation induced damage. This property of ferulic acid has led to its application in the prevention of food spoilage due to the inhibition of lipid peroxidation and as an additive to soft drinks. As an effective antibacterial agent, it is also useful in the preparation of antibacterial succinic acid derivatives with biodegradable potential (Ryan *et al.*, 2011). The whole grain rice health benefits are of highly related with the bioactive food components specifically, gamma oryzanol (GO), gamma amino-butyric acid (GABA), and ferulic acid (FA) in the embryo and rice bran (Sing *et al.*, 2015). The germinated rice comprises of higher quantities of ferulic acid (Jirapa *et al.*, 2016). Ferulic acid has the ability to inhibit the build-up of superoxide, regulating the accumulation of blood platelets and lowering cholesterol also having antioxidant properties (Jirapa *et al.*, 2016).

Flavonoids: Flavonoids are among the most important compounds in the human diet (Jirapa *et al.*, 2016) and these polyphenols are originated from the plant. These compounds are found both in free form (aglycones) and as glycosides, and differ in their substituents such as type, number and their position. The most acquainted classes of flavonoids are the anthocyanidins, catechins, flavones, flavonols, flavanones, and isoflavones, which account for around 80% of the total flavonoids (Pinheiro and Justino, 2012; Jirapa *et al.*, 2016). Flavones are usually encountered as flavonoids in non-pigmented rice varieties. Tricin is a foremost flavonoid in the rice bran, and it accounts for about 77% of all the seven

flavonoids that are reported in rice (Goufo and Trindade, 2014).

Anthocyanin and proanthocyanidin: Anthocyanins and proanthocyanidin are another class of flavonoids present in rice (Boue *et al.*, 2016). These compounds are water-soluble glycosides of polyhydroxyl and polymethoxyl derivatives of 2-phenylbenzopyrylium salts. There have been 18 anthocyanins identified in rice to date (Goufo and Trindade, 2014). The pigmented rice are source of antioxidant compounds including phenolic compounds, anthocyanin, proanthocyanidin, flavonoid, phytic acid, tocopherols, tocotrienols and γ -oryzanol (Thitipramote *et al.*, 2016). The rice pigments are classified into red, purple and, black color by the types of pigment compounds like proanthocyanidin and anthocyanin (Thitipramote *et al.*, 2016).

γ -oryzanol: In the refining industry, the residues produced from the rice bran oil are rich in tocopherols, vitamin E, ferulic acid, phytic acid and γ -oryzanol (Kozuka *et al.*, 2015; Huang *et al.*, 2016). γ -oryzanol in rice is known to be an antioxidant compound that is associated with the effects of decreasing the plasma cholesterol, lowering serum cholesterol, and inhibiting cholesterol absorption (Patel and Naik, 2004). γ -oryzanol is also used as a sun screen agent for protection against UV-light induced lipid peroxidation along with its use in some revitalizing tonics and medicinal drinks (Iqbal *et al.*, 2004).

Rice bran oil is rich in γ -oryzanol and is therefore a potential source of antioxidants for the food, cosmetic and pharmaceutical industries (Patel and Naik, 2004). γ -oryzanol contains a number of compounds such as campesteryl ferulate, cycloartenyl ferulate, cyclobranlyl ferulate, sitosteryl ferulate, 24-methylenecyclo artenyl ferulate and stigmasteryl ferulate in variable quantity (Berger *et al.*, 2005; Saikia and Deka, 2011). Goufo and Trindade, (2014) have reported that distribution of γ -oryzanol in different rice tissues was found to occur in the order of bran (3174.2-3176.4 mg kg⁻¹) > whole grain (413.3-473.3 mg kg⁻¹) > husk (102.4-323.2 mg kg⁻¹) > endosperm (49.1-231.8 mg kg⁻¹). Numerous researches have described about the health benefits of γ -oryzanol, like reduction of total plasma cholesterol and increase of HDL cholesterol levels, inhibition of the platelet aggregation, improvement of plasma lipid pattern, and its antioxidant activity (Ekasit and Jiraporn, 2013).

Phytosterols: Although sterols are a component of γ -oryzanol, most of the sterols in rice bran oil are free phytosterols. These compounds act in the gastrointestinal tract of humans to inhibit the absorption of cholesterol (Pitija *et al.*, 2013). The Rice bran comprises major quantities of phytochemicals including phytosterols which are helpful for human health. For antioxidant activities tocopherols, tocotrienols and γ -oryzanol components in the extract of pigmented rice bran are highly acknowledged (Somintara *et al.*, 2016).

Phytic acid: Inositol hexa phosphate (i.e., phytic acid) is the major nutritionally relevant form of inositol found in rice. The primary functions of phytic acid in rice are storage of phosphates as source of energy and as natural antioxidants during the germination process (Liu *et al.*, 2005). Phytic acid in rice is considered an anti-nutrient because the negatively charged phosphate in phytic acid binds strongly to the metallic cations (K, Mg, Ca, Fe, Zn and Mn), which makes them insoluble, resulting in mineral deficiencies in the diet. Phytic acid and its derivatives have also been implicated in export of RNA, repair of DNA, cell vesicular trafficking, endocytosis and signaling. However, the effects of phytic acid in rice bran holds much promise owing to its ability to inhibit the abnormal proliferation of cell and prevent metastasis (Vucenik and Shamsuddin, 2003). It is reasonable to control the amount of phytic acid in them to a level at which the medicinal and health potential of the grains can be maintained and the availability of minerals is not greatly altered (Febles *et al.*, 2002; Liu *et al.*, 2005; Lee *et al.*, 2015).

Nutraceutical Potential of Different Varieties of Rice:

Rice and its various components are used as medicine in many countries including China, Korea, Japan, India, the Philippines, Malaysia and Cambodia (Umadevi *et al.*, 2012).

The medicinal value of rice has been described in the Indian traditional medicine book, Ayurveda. Specifically, rice is reportedly useful as a tonic, acrid, aphrodisiac, diuretic, oleaginous and in biliousness (Umadevi *et al.*, 2012). B-complex vitamins, especially thiamin, riboflavin and niacin present in natural brown rice, help promote youthful energy that nourishes the skin and blood vessels (Umadevi *et al.*, 2012). Rice has long been used to treat a variety of health disorders, such as high blood pressure, dysentery and poor skin (Oudhia, 2000; Umadevi *et al.*, 2012; Abubakar *et al.*, 2016). The nutritional factors in rice byproducts includes cellulose, hemicellulose, hydrocolloids, lignin and pectins and many others (Oudhia, 2000). Some of the nutraceutical potential of different rice varieties is discussed below (Fig. 2). **Antioxidant properties:** Bioactive compounds with antioxidant potential in rice have been categorized into six major groups including, anthocyanins and proanthocyanidins, flavonoids, phenolic acids, tocopherols and tocotrienols (vitamin E), γ -oryzanol, and phytic acid (Iqbal *et al.*, 2004; Ghose *et al.*, 2013; Goufo and Trindade, 2014; Abubakar *et al.*, 2016). Among these compounds, the polyphenols present in the pericarps of rice are the most vital antioxidant compounds connected with the reduction of various types of

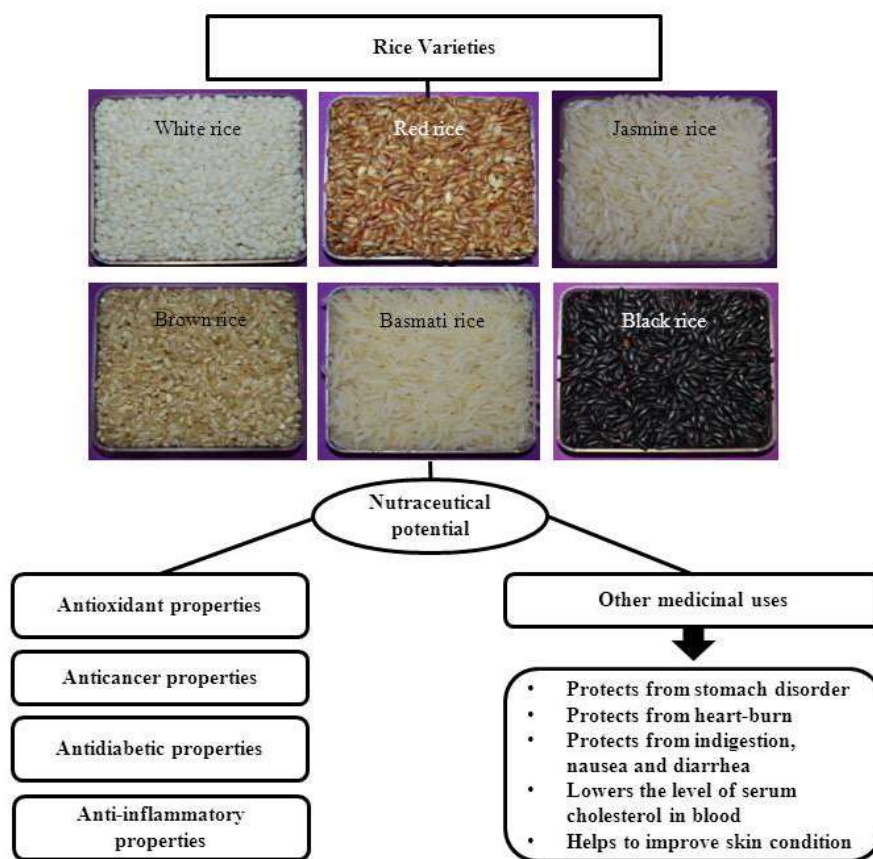


Figure 2. Different varieties of rice grains with medicinal potentials.

oxidative stress (Hu *et al.*, 2003; Holden *et al.*, 2005). The minor components of rice bran (i.e., γ -oryzanol and phytosterols) also possess antioxidant properties. At elevated temperatures, ferulic acid ester of γ -oryzanol is known to be a potent antioxidant compound with stabilizing properties. There is report about rice grains with red, black and light brown pericarp colors and the total soluble phenolic compounds and their antioxidant activity (Walter *et al.*, 2013). In brown rice the existence of significant amount of antioxidants and minerals with changing cooking properties and the effect of variety difference in antioxidant property, mineral content is proved (Mir *et al.*, 2016).

Anticancer properties: Rice is rich in polyphenolic compounds, which are known to reduce the number of tumors and their growth (Pandey and Rizvi, 2009). Whole grain rice such as brown rice is rich in different types of insoluble fiber that can be used for treatment of different types of cancers (Umadevi *et al.*, 2012). For example, the extracts from brown rice are used to treat stomach and breast cancer (Chen *et al.*, 2006). Various studies have shown the effects of tocotrienols present in rice as an anticancer agent (Miyazawa *et al.*, 2008; Kannappan *et al.*, 2010; Cho *et al.*, 2016). Henderson *et al.* (2012) have reported that the rice bran containing γ -oryzanol, ferulic acid, caffeic acid, tricin, and β -sitosterol, exerts chemo preventive activity.

Antidiabetic properties: There are many bioactive compounds in rice, as well as products such as acylatedsteryl β -glucoside, dietary fiber, phenolics, γ -aminobutyric acid, γ -oryzanol and vitamins, which could help prevent human diabetes. In management of type 2 diabetes, the use of dietary fiber as hypoglycemic drugs in germinating brown rice lowered the glycemic index through regulation of the absorption of glucose in the intestines (Imam *et al.*, 2012; Abubakar *et al.*, 2016). Yawadio *et al.* (2007) have reported that the concentration of total phenolics in rice grain helps to prevent complications associated with diabetes.

Other potentials: Sticky glutinous rice is commonly used in treatment of diarrhea, indigestion, nausea, heart-burn and stomach disorders (Jayadeep and Malleshi, 2011). This type of rice reduces the level of cholesterol in the blood. Rice bran helps to decrease the level of unscrupulous low density lipoprotein and increases the level of noble high density lipoprotein, aiding in cardiovascular health (Berger *et al.*, 2005; Pode, 2016).

Conclusions: Rice is a staple food and an important cereal crop that feeds more than 50% of the world population. Although rice is one of the oldest cultivated grains, its medicinal properties have not been extensively explored. Rice is rich in many bioactive compounds such as γ -oryzanol, tocopherol, tocotrienol, phytosterol, ferulic acid, p-coumaric acid, gallic acid, caffeic acid and polycosanols and dietary fibers such as betaglucan, pectin, and gum. However, its medicinal potentials have been underutilized due to lack of

knowledge regarding its nutritional values and difficulties in its usage due to the existence of free fatty acids. Previous studies indicated that intake of foods rich in natural antioxidants such as polyphenols and flavonoids, as well as in bioactive compounds, have beneficial effects on many degenerative diseases including cardiovascular disease, cancer, diabetes, dysentery, high blood pressure, and heart disease. Therefore, further investigations of potential uses and applications of rice in food and pharmaceutical industries for the development of nutrient rich foods and new drugs for treatment of various diseases are warranted.

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