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Rice: Bioactive compounds and their health benefits

Arsha RS, Prasad Rasane and Jyoti Singh

Abstract
Rice is the primary source of calories in many developing countries, and about 60% of the world's population consumes rice as a staple food. Rice has high nutritional value such as carbohydrate, fat, fibre, protein, vitamins as well as food energy, minerals profile and fatty acids. The processing steps of rice is cleaning, parboiling, drying, dehusking, partial milling, grading, packing and storage. The pigmented rice varieties are available with reddish, purple or even blackish colour. Various extraction methods are used for extraction bioactive compounds from rice including traditional methods (like Soxhlet extraction method and maceration method) to modern methods (like accelerated solvent extraction method (ASE), solid-phase extraction (SPE), pressurized liquid extraction (PLE), pressurized fluid extraction (PFE), subcritical water extraction (SWE), subcritical fluid extraction (SFE), microwave-assisted extraction (MAE), vortex-assisted extraction (VAE), ultrasound-assisted extraction (UAE)) and their combinations. In addition to nutritional components, rice contains a number of phytochemicals, they are the source of bioactive components such as Phenolic compounds (like capesterol, caffeic acid), flavanoid (anthocyanin and proanthocyanin), γ-oryzanol, carotenoids (like α-carotene, β-carotene, lyopene, lutein),phytosterils (like β-sitosterol, sligmasterol and capesterol),the vitamin E isoforms (α–, γ–, δ–tocopherols and tocotrienols), phytic acid, coumaric acid, tricin etc with a variety of biological activities, the most significant of which are antioxidant, anticancer, anti-diabetic, and anti-inflammation and also exhibit their potential beneficial health effects in human as they all consume rice in their daily routine diet. This review mainly focus on the bioactive components of rice and their health benefits.

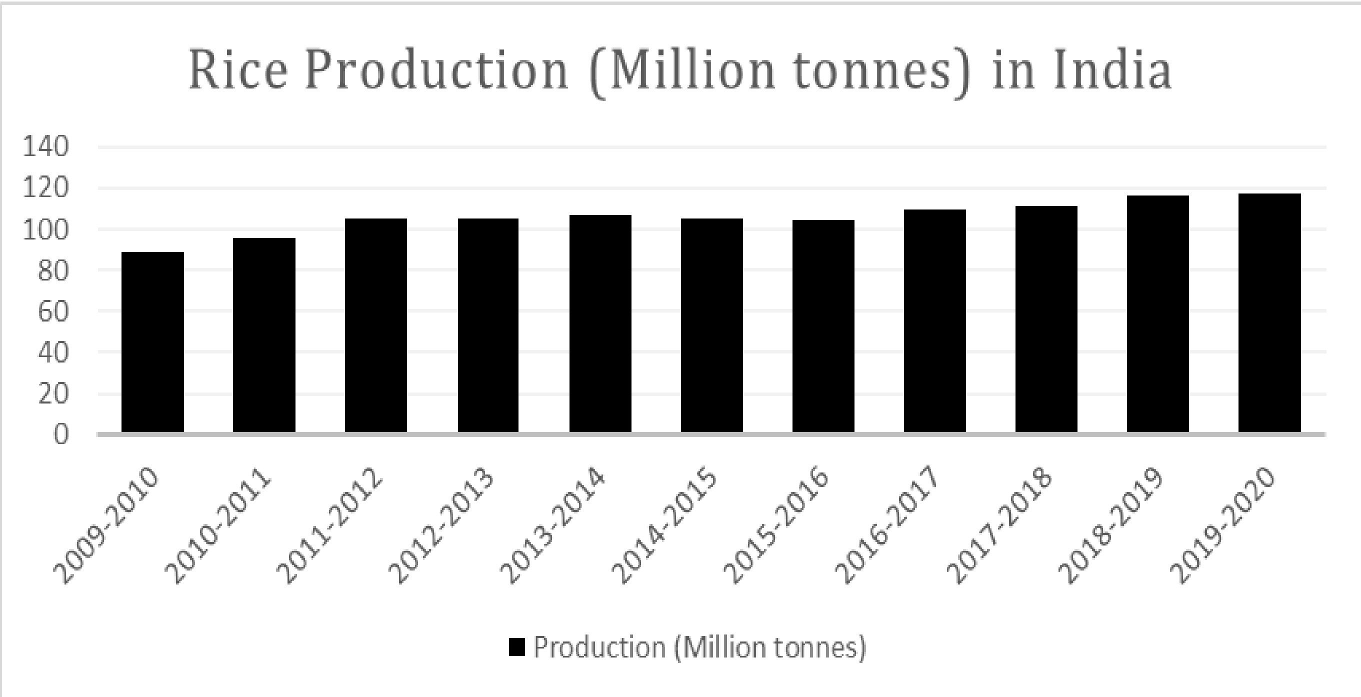
Keywords: anti-diabetic activity, antioxidant activity, extraction, phenolic compounds, rice

1. Introduction

Rice (*Oryza sativa* L.) is the most important crop in India as a staple food which providing nutrition to the population. For Asians, rice is known as "Grain of life", and is compatible with food. It is an essential part of rituals, ceremony and festivals. It also has medicinal values (Chaudhari *et al*, 2018) [5]. The global production of rice paddy was 739.1 million tonnes in 2015, which yielding 490.5 million tonnes of white rice. In Asia, the production of rice paddy was 668.4 million tonnes that is 90% of the global population. The environment stability of growing rice paddy at different temperature, humidity and soil conditions make it possible for rice to become a globally viable crop (Ravichanthiran *et al*, 2018). Rice is a rich source of carbohydrate, with a small quantity of protein, fat as well as vitamin B complexes like niacin, riboflavin and thiamine (Fresco, 2005). Carbohydrates are basically starch made up of amylose and amylopectin. Rice consists of 12% water, 75-80% starch, and just 7% protein. It is extremely digestible (93%) with high biological value (74%) because of its higher concentration of lysine (≈4%) and protein efficiency ratio (2.02% - 2.04%) (Juliano, 1993). Minerals like phosphorous (P), calcium (Ca), magnesium (Mg) combined with some traces amount of iron (Fe), zinc (Zn), copper (Cu) are also present. An indigenous medicinal rice variety called "Njavara" which is cultivated in Kerala and matures in 70 days. It has two categories such as "Black glumednjavara" and "Yellow glumednjavara", on the basis of colour of its outer paddy cover (Kang *et al*, 2015). Some rice varieties of Arunachal Pradesh, India are rich in pigmented rice and major source of bioactive compounds like phenolic acid, flavones, anthocyanin etc (Samyor *et al*, 2016). In red rice, brown, black, purple and brown red rice, major bioactive components areprotocatechuic, gallic, hydroxybenzoic, sinapic acid, ferulic, pcoumaric, cyanindic-3-O-glucoside, peonidin-3-O-glucoside,flavan-3-ol (+) catechin and (-) epicatechin, flavanols (flavan-3-ols), isoflavines, c-oryzanol content, compositions of steryl, tocopherol and triterpene alcohol ferulates proportions (Samyor, 2017) [39]. Extraction is the first step in the preparation of cosmetics, food ingredients, pharmaceutical products, nutraceuticals, and dietary supplements products using rice bioactive compounds. Before extraction of bioactive compounds, the rice is treated with various processing steps such as milling, grinding and homogenization, which maintain higher amount of bioactive compounds (Bar *et al*, 2011). Various extraction methods are used for extraction bioactive compounds from rice including traditional methods (like Soxhlet extraction method and maceration method) to modern methods (like accelerated solvent extraction method (ASE), solid-phase extraction (SPE), pressurized liquid extraction (PLE), pressurized fluid extraction (PFE), subcritical water extraction (SWE), subcritical fluid extraction (SFE), microwave-assisted extraction (MAE), vortex-assisted extraction (VAE), ultrasound-assisted extraction (UAE)) and their combinations (Verma & Srivastav, 2020, Ciulu *et al*, 2018) [49, 8] Anti-oxidant activity, anti-cancer activity, anti-diabetic, anti-inflammatory, anti-aging, anti-allergic, lower cholesterol are the major health benefits of bioactive compounds in rice.

2. Worldwide Cultivational Practice of Rice

Rice is grown in all the six continents of the world such as Asia, Africa, Australia, Europe, North America, and South America, where field crop production is practiced with the exception of the icy continent of Antarctica, where no crops are grown. Around 80% of the world's rice-growing region is in eight Asian countries: China, India, Indonesia, Bangladesh, the Philippines, Vietnam, Thailand, and Myanmar. These aren't just any eight countries among the UN's 200 countries; they account for 46.6 percent of the world's population. Asia accounts for 90% of the world's rice production. China had the largest share of total rice production in 2010, at 30.1 percent, which is expected to drop to 27.3 percent by 2021–2022, whereas India's share is expected to rise marginally from 21.5 percent in 2010 to 22.4 percent in 2021–2022. Over the period 2010–2021, Asia's share of global rice production is expected to fall gradually from 89.9 to 89.3 percent, whereas Africa's share is likely to increase from 3.4 to 4.2 percent (Wailes and Chavez 2012) [50]. Milestones in the Development of Modern Rice Varieties are Indica–Japonica Crosses, high-yielding fertilizer responsive varieties such as IR-8, hybrid rice, basmati rice, genetically modified rice (Golden rice), NERICA rice, and aerobic rice. Single rice cropping per year, annual rice-upland crop rotations, and double rice cropping per year are the three main rice cropping trends in China. Northern China is home to the single rice cropping system, which accounts for 17 percent of China's total rice production. Central China is home to the annual rice-upland crop rotation scheme like rice-wheat or rice-rapeseed rotation and it's around 49% of total Chinese rice production. The double rice cropping system, which is primarily found in South China, accounts for 34% of China's total rice production (National Bureau of Statistics of China 2011) [54]. Manual transplanting, direct seeding (both manual and mechanical direct seeding), throwing transplanting, mechanical transplanting, and ratooning rice are the most popular rice planting methods in China. The majority of rice was grown by direct seeding in Europe, America, and Australia, whereas farmers in Japan and South Korea mostly used mechanical transplanting and, to a lesser extent, mechanical direct seeding. In India, transplanting young seedlings into puddled soil (wet tillage) is the most popular method for rice establishment. However, since this approach is water, labor, and energy intensive, and these resources are becoming increasingly scarce, it is becoming less profitable these days (Kumar and Ladha 2011) [22]. The major rice producing states were West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Orissa, Madhya Pradesh and Bihar. These states together accounted for approximately 75 percent of the country's overall production of rice (Prasanna *et al*, 2009) [33]. India widely cultivating rice varieties are Basmati, Navara, Jaya, Jyothi, Ponni, Palakkadan matta, Pusa, Boli, Sona Masuri, Kalajiri(aromatic rice) etc. The coloured rice varieties are Himalayan red rice, kattamodon, palakkadan matta rice, kairali, rakthashali of Kerala, asha, jyothi, bhadra, kaivara samba, mappillai samba, red kavuni, kuruvi kar, poongar of Tamilnadu etc (Priya *et al*, 2019) [34]. In Europe, Japonica rice varieties are the most common. Rice is cultivated in the spring and harvested in the autumn. European rice production can never contribute to a global overproduction. But it helps to safeguard domestic demands.



Rice production in India (2009-2020) (Ravichanthiran *et al*, 2018)

3. Nutritional Composition of Rice

When compared to maize, wheat and potatoes, long grain white rice is rich in carbohydrates, calcium, iron, thiamine, panthothenic acid, folate and vitamin E. It does not containing vitamin A, vitamin C, β-carotene, lutein, xeaxanthin and poor source of dietary fibre. Red coloured rice varieties are rich in iron and zinc, whereas the other side black rice varieties are highly rich in protein, fat and crude fibre. The colour giving pigment in coloured rice varieties is anthocyanin, which are considered to have free radical scavenging and antioxidant capacities, and also health benefits. Brown rice has low calorie and highly rich in fibre content. It is also a good source of magnesium, phosphorous, selenium, manganese, thiamine, niacin, vitamin B6 (Priya *et al*, 2019) [34]

3.1. Carbohydrate

Rice is a complex source of carbohydrates. Carbohydrate found as starch form, it is approximately 75-80% (Verma and Srivastav, 2020) [49]. The key types of starch present in the rice grain are amylose and amylopectin. These can be defined as soluble carbohydrates and crude fibre. Rice also contains sugar that is free, such as fructose, raffinose, glucose, dextrose, etc. The portion of carbohydrate is greater in milled rice than brown rice. The portion of carbohydrate fibre does not get digested. Type 2 diabetics patients would be better to eat slowly digestible rice varieties than white rice (Chaudhari *et al*, 2018) [5].

3.2. Protein

Second major component, next to starch. It affects the nutritional quality of rice and eating quality. The dietary supply of rice per person per day in India is 207.9g, which provides around 24.1percent of the dietary protein required. The colored rice has high protein content than polished white rice because of the presence of bran. (Priya *et al*, 2019) [34]. Pre-germinated brown rice has double protein content than white rice, i.e. 14.6 g/100g in brown rice and 7.3 g/100g in white rice (Rohman, 2013). The lysine content of rice protein, making it the highest among cereal proteins, is between 3.5 and 4.0 percent. The endosperm protein consists of 15% albumin (water soluble), 5-8% prolamin (alcohol soluble), globulin (salt soluble) and the remaining of glutelin (alkali soluble) (Juliano , 1992).

3.3. Fat

The Fat found in rice is rich in linoleic acid and other essential fatty acids. The lipids or fats in rice are predominantly limited to rice bran. Cholesterol is not present in rice. The starch lipids found in rice are composed of amylose-complexed monoacyl lipids (fatty acids and lysophosphatides). It is present in the aleurone layer and bran, as lipid bodies. The lipid centre is rich in lipids, and linoleic, oleic and palmitic acids are the main fatty acids. Fat content of pre-germinated brown and white rice is 24.8g/100g and 1.5 g/100g (Rohman, 2013).

3.4. Dietary fibre

Dietary fiber helps to reduce serum cholesterol, low density lipoprotein and blood pressure, and to improve glycaemia and insulin sensitivity. Brown rice contains fiber three times more than white rice (Upadhyay & Kumar Karn, 2018) [48]. In pigmented rice, the dietary fibre content was high, 9-10 g/100 g compared to non-pigmented, ~6 g/100 g. The soluble fibre content ranged from 1 to 1.5 g/100 g in the pigmented head rice (dehusked) and varied from 0.45 to 1.45 g/100 g in the broken rice. In parboiled rice, the dietary fibre content was limited by about 1 percent. The total fibre content in the parboiled rice of the pigmented varieties varied from 7.95 ± 0.15 to 9.05 ± 0.25 g/100 g and the soluble fibre content varied from 0.7 to 0.9 g/100 g (Savitha & Singh, 2011) [40].

3.5. Vitamin

Vitamin B (especially thiamine, riboflavin and niacin) is rich in brown rice which prevent vitamin deficiency diseases (Upadhyay & Kumar Karn, 2018) [48]. The vitamins B are concentrated in the rice grain's Bran layer. It also contain α-tocopherol (vitamin E). The rice lacks vitamin A, D or C. 50% of the total thiamine in rice grain is present in the scutellum and 80-85% niacin is in the pericarp and aleurone layer. The embryo contains 95 percent of the total tocopherol and one-third of the rice grain's oil content.39% of riboflavin is present in the bran and only 8% is retained in the polished rice and 53% is present in the milled rice fractions.

3.6. Minerals

Brown rice is an excellent source of minerals. Major minerals such as phosphorous was found in highest amount (354 mg/100g), calcium (11.6 mg/100g), magnesium (216 mg/100g), potassium (304 mg/100g) and sodium (30.8 mg/100g) in Njavara rice. These minerals are helpful in improving muscle activity in muscle wasting patients. Red and black rice is rich in iron (Fe) and zinc (Zn) (Ahuja *et al*, 2008) [2].

Nutritional composition of rice

Component of rice	Availability of rice	References
Moisture	14-20%	Klomklao *et al*. (2017)
Carbohydrate	80%	Chaudari *et al*. (2018)
Protein	4-14%	Kennedy *et al*. (1975)
Fibre	Dietary 4g Water insoluble -2.7g Lignin -0.1g	Fernando. (2013)
Fat	1-2%	Priya *et al*. (2019) [34]
Ash	Ca- 32mg/100g P- 22mg/100g Fe- 1.6mg/100g K- 9mg/100g Iron-8.6-43.0mg Zinc-4.3-25.8mg	Verma and Shukla. (2011) Chaudari *et al*, (2018)
Calories	370kcal	Rohman *et al*. (2014)
Phytochemicals	phenolics- 70.3mg/100mg	Moongngarm&Saetung (2010)

	Flavonoids-1.93mg/100mg Anthocyanins-345.8mg/100g Phytic acid-1.32 mg/100mg α-Tocopherols-0.93mg/ 100mg γ-oryzanol-66 mg/100 g	PENGKUMSRI(2015) Verma & Srivastav (2020) [49]

4. Processing techniques of rice

After several processing operations, the rice is obtained from paddy grains. The paddy crop is harvested and threshed for separation of paddy from stalks after desired maturity. Threshing just removes the spikelets, along with the glumes, from the plant. Until the threshing is finished, to become edible rice, the paddy has to undergo multiple unit operations (Nambi *et al*, 2017). There are two key operations in paddy production, i.e. shelling or dehulling and milling or polishing. In the case of parboiled rice, the paddy is parboiled and dried before shelling and milling takes place. The processing steps are cleaning, parboiling, drying, dehusking, partial milling, grading, packing and storage.

4.1. Cleaning: The purpose of cleaning is based on the different physical properties like the weight, density, size and properties of impurities, impurities in paddy lighter than paddy which are removed by aspirator.

4.2. Parboiling: It is an ancient method for rice processing. Various parboiling techniques and equipment are available now. Modern methods of parboiling are energy and capital intensive, but they are not suitable for small scale operations. In small scale operations we use parboiling equipment range from pottery to boiler, direct or indirect heating and single or double steaming, which consume all different amount of energy. For direct heating, vessels are used and for indirect heating, small and medium boilers are used. The common unit operations are pre-steaming, soaking, soaking, steaming, drying, milling. Then the outcome is parboiled rice.

4.3. Drying: To obtain the desired milling and storage properties, the parboiled paddy must be dried to a moisture content of 14–16 percent. Drying is traditionally done in open yards (sun drying), and the process can take up to 5 days depending on the weather conditions. Continuous drying systems using hot air are used in modern rice mills to make the process fast and sanitary.

4.4. Dehusking: Dehusking or dehulling, or more generally shelling, is the act of extracting the husk. Mechanical separation of the hull or husk from the paddy grains is achieved. To improve the efficiency of the dehusking method, a variety of machines with various operating principles have been developed.

4.5. Seperation: The dehusking machine will produce a mixture of dehusked rice (brown rice), husks, and unhusked paddy as its product. To differentiate the desirables from the undesirables, this mixture is sieved-cum aspirated.

4.6. Milling or Polishing: Milling or polishing is the process of removing bran layers. Abrasive and friction polishers are the two styles of polishers widely used at the commercial level in rice milling.

4.7. Grading: The milled rice includes head rice (unbroken rice) and brokens of various sizes after polishing operations. Stage sieving machines are used to separate brokens from head rice.

4.8. Bagging and Storage: Automatic weighers and baggers are used to pack predetermined amounts of rice (by weight). Dust-free bagging and finished product are ensured by a continuous and enclosed flow through conveyors and pipes.

5. Bioactive compounds of rice

Rice is made-up of phytochemicals and nutrients. They are the source of bioactive components such as Phenolic compounds (like capesterol, caffeic acid), flavanoid (anthocyanin and proanthocyanin), γ-oryzanol, carotenoids (like α-carotene, β-carotene, lyopene, lutein),phytosterils (like β-sitosterol,sligmasterol and capesterol),the vitamin E isoforms (α−, γ−, δ−tocopherols and tocotrienols),phytic acid, coumaric acid, tricin etc (Verma and Srivastav, 2020) [49].

5.1. Phenolic compounds

Phenolic acids are also known as poiyphenol. It is generally found in two forms such as free and bounded. They are made up of phenolic ring and organic carboxylic acid, and its peak absorbance at 280 nm for hydroxybenzoic acid and at 320 nm for the hydroxycinnamic acid. Hydroxybenzoic acid contains gallic acid, syringic acid, vanillic acid, p-hydroxybenzoic, protocatechuic. Hydroxycinnamic acid contains caffeic acid, chlorogenic, cinnamic, ferulic, sinapic acids, p-coumaric. Around 70-90 percent of the concentration of phenolic acids in rice bran is recorded i//n the percarp of light brown rice (Verma and Srivastav. 2020) [49]. Total phenolic content was assayed by the Folin-Ciocalteu colorimetric method (Shao *et al*, 2018) [43]. Total phenolic content in brown rice 161.42 – 374.81mg/g (Z.Hu *et al*, 2017), red rice 162.86–415.10mg/100g (Shao *et al*, 2018) [43], and black rice is 117.6 ± 14.6mg/g (Limtrakul *et al*, 2019) [25].

5.2. Flavonoids

Colorimetric method was used to determine total flavonoid content. It was calculated by using the standard rutin curve, and denoted as mg rutin equivalent (mg RE) per 100g of dry weight (Shen *et al*, 2008). The most common flavonoids of rice are flavonols, flavonols (flavan-3-ols), flavones, flavanons, isoflavones etc (ciulu *et al*, 2018) [8]. Most flavonoids have the highest absorbance at 370 nm (Verma and Srivastav. 2020) [49]. Tricin seemsto be the major flavanoid in bran, accounting for 77 percent of all seven flavonoids (131.5mg/100g) that are generally reported in rice. Flavones are the most commonly found flavanoids in non-pigmented rice varieties (Goufo, P., &Trindade, H. 2014) [13]. Total flavonoid content in brown rice is 106.5 ± 54.4mg/100g (Goufo, P., & Trindade, H. 2014) [13], red rice 147.2 ±18.0mg/100g (Shen, *et al*, 2009) [44], black rice 240.6 ± 38.1mg/100g (Shen *et al*, 2008).

5.2.1 Anthocyanin

Anothocyanins are another class of flavonoids, which exhibit maximum absorbance in the green/blue spectrum at 510nm. It is expressed as available standards or as cynidin-3-O-glucoside equivalents when standards are not available (Caro, 2013).They are the primary functional components of pigmented rice (Samyor, Das and Deka, 2017) [39]. Around 18 anthocyanins are seen found in rice, in this four have been quantified (cyaniding-3-O-glucoside, peonidin-3-O-glucoside, cyanidin-3-O-rutinoside, and cyanindin-3-O-galactoside) (Goufo, P., &Trindade, H. 2014) [13]. Total anothocyanin content in red rice range from 0.3-1.4 and in black rice, it is 109.5-256.6 mg/100g (Sompong *et al*, 2011) [45].

5.2.2 Proanthocyanidin
Proanthocyanidins (Condensed tannins) are polymers with high molecular weight. They are complex flavonoid polymers which are found in some cereals and legume seeds (Samyor, Das and Deka, 2017) [39]. Total proanthocyanidin content was determined using vanillin assay and the absorbance at 500nm by using microplate reader (Seawan *et al*, 2013). The results were expressed as mg CE/100g (milligram of catechin equivalent per 100 gram of dry rice flour) (Shao *et al*, 2017). Total proanthocyanidin content in red rice was 53.45 ± 3.23mg/100g (Limtrakul *et al*, 2019) [25].

5.3 γ-oryzanol
γ-oryzanol is a combination of steryl ferulates that are formed by esterification of the hydroxyl group of sterols or triterpene alcohols with the carboxylic acid group of ferulic acid. γ-oryzanol helps to reduce the risk of the incidence of tumors, to inhibit platelet aggregation, and to have anti- inflammatory effects (Heinemann *et al*, 2008). Other than health benefits, γ-oryzanol is used as an additive in food industry to improve storage stability (Minatel *et al*, 2014) [27] γ-oryzanol content in brown rice is 46.4-2.56mg/100g, red rice 45.2-0.60mg/100g and in black rice 80.1-2.73mg/100g (Minatel *et al*, 2014) [27].

5.4 Carotenoid
Carotenoids are yellow-orange pigments, which are mainly divided into a) carotenes (α- and β- carotenes. β-carotenes was a provitamin A carotenoid, reduce the risk of cancer and cardiovascular diseases b) xanthophylls (Lutein and zeaxanthin both are non-provitamin A carotenoids, which are present in eye and protect against eye diseases) (Lamberts & Delcour, 2008). It was determined by HPLC method (Minatel *et al*, 2014) [27] and quantified at 450nm. The carotenoid content in brown, red, black and white rice are 0.08, 0.5. 6.6 and 0.008 mg/g respectively (Caro *et al*, 2013).

5.5 Vitamin E
Vitamin E is also known as tocols. It is a common term for a group of four tocopherols (α, β, γ, and δ) and four tocotrienol (α, β, γ, and δ). Total vitamin E content in red rice was 19.36-37.00 mg/kg and in black rice,it was 28.54-63.29mg/kg (Samyor, 2016). It is determined by using HPLC system (Minatel, 2014) [27].

Some Bioactive Compounds Present In Brown Rice, Red Rice& Black Rice

Bioactive compounds	Rice varieties (mg/100g extract)			Reference
	Brown rice	**Red rice**	**Black rice**	
Total phenolic content	161.42– 374.81	162.86–415.10	117.6 ± 14.6	Z.Hu *et al*, (2017), Shao, *et al*, (2018) [43] Limtrakul *et al*, (2019) [25]
Total flavonoid content	106.5 ± 54.4	147.2 ±18.0	240.6 ± 38.1	Goufo, P., &Trindade, H. (2014) [13], Shen, *et al*, (2009) [44], Shen *et al*, (2008)
Vanillic acid	2.65–4.74	1.53±0.19	-	Ravichanthiran *et al*,(2018), Limtrakul *et al* (2019) [25]
Γ-Oryzanol	46.4 – 2.56	45.2 – 0.60	80.1 – 2.73	Minatel *et al*, (2014) [27],
Coumaric acid	0.10 ± 0.00	0.2 ± 0.01	0.5 ± 0.2	Verma & Srivastav (2019), Caro *et al* (2013). Tian (2004) [46]
Proanthocyanidin	-	53.45 ± 3.23	-	Limtrakul *et al*, (2019) [25],
Anthocyanidin	-	4.3 ± 1.4	8.1 ± 1.9	Limtrakul *et al*, (2019) [25], Caro *et al* (2013).

6. Extraction methods for bioactive compounds
For the extraction of bioactive components from pigmented rice, several extraction techniques such as solvent extraction, supercritical fluid extraction and subcritical water extraction have been developed. The solvent extraction is conventional method for the extraction of bioactive compounds from pigmented rice by using organic solvent such as acetone, methanol and ethanol and water in a certain proportion as solvents for extraction.

Microwave assisted extraction (MAE) method is another extraction technique. Here the microwave radiation for the extraction of phenolic compounds from rice was reported. In this method, the breakdown of the weak hydrogen bond due to the dipole rotation of the molecules promotes the extraction of the analytes. A main advantage of the microwave-assisted extraction (MAE) is the possibility to obtain phenolic compound-rich extracts in a short time (Setyaningsih *et al*, 2015) [42].

Extraction of phenolic compound from rice (Microwave Assisted Extraction method)
(Ciulu *et al*, 2018) [8]

Accurately weigh 2.5g of rice powder and placed into an extraction vessel

Microwave Assisted Extraction
Temperature: 185 ºC
Microwave power: 1000 W
Time: 20min
Solvent: 100% methanol
Solvent/Sample ratio: 10/1

After extraction the vessels are cooled in an ice bath for 10 min and opened

The solid material in the sample is filtered off and washed using fresh solvent

The combined filtrate and washings are evaporated to dryness

The residue is dissolved in methanol (2ml)

7. Health Benefits of bioactive compounds
Coloured rice consumption is rich in beneficial bioactive compounds will help to promote some health benefits such s anti-oxidant activity, anti-cancer, anti-diabetic, Anti-inflammatory, skin anti-aging, anti-allergic, anti-atherosclerosis, anti-tumour, alleviating gallstones, lowers cholesterol etc.

7.1. Anti-oxidant activity
Pigmented rice are also known as the source of antioxidant compounds including flavanoid, phenolic acids, anthocyanins, proanthocyanins, γ-oryzanol, tocopherol, tocotrienolsand phytic acids (Thitipramote *et al*, 2015). Black rice shows highest anti-oxidant activity when compared to purple, red and brown rice varieties (Goufo & Trindade, 2014) [13]. Anti-oxidants have protective functions against oxidative damage, and help to reduce the risk of chronic diseases (Adom &Liu, 2002) [1].

7.2. Anti-cancer activity
The chemo-preventive and anticancer ability of certain biologically active molecules present in germinated brown rice has been reported in recent studies. Colon cancer was produced with the use of azoxymethane in six week old male Sprague-Dawley rats, followed by oral administration by a control diet or varying doses of germinated crude extract (2000,1000 and 5000 mg/kg body weight) once daily for eight weeks. The study showed a dose dependent decrease in the size and number of aberrant crypt foci formation and β-catenin expression in rats fed crude extract of germinated rough rice (Ravichanthiran *et al*, 2018).

7.3. Anti-diabetic activity
The highest risk of developing type II diabetes and other complicated health problems for pre-diabetic patients (Samyor *et al*, 2017) [39]. Metabolic improvements due to germinated brown rice that can be helpful in the management of type 2 diabetes include better glycemic control, reduced type 1 tissue plasminogen, amelioration of oxidative stress, correction of dyslipidemia, and increased sodium potassium denosine triphosphatse and homocysteine thiolactonase activities (Imam *et al*, 2012) [15]. Using an open-labelled, randomized cross-over study design, they observed that there was a significant decrease in postprandial plasma glucose, haemoglobin A1c (HbA1c) and glycoalbumin levels in patients who ate glutinous brown rice two times day when compared to those who are white rice. These effects are due to the rich bioactive content found in brown rice (Ravichanthiran *et al*, 2018).

7.4. Anti-inflammatory activity
A significant mechanism of immune pathogenesis is called inflammation, which is the response of our body to tissue infection, injury and stress. Some reports have shown that lipophilic phytochemicals such as γ-oryzanol and vitamin E derivative contained in pigmented rice germ and bran exert anti-inflammatory activity (Limtrakul *et al*, 2019) [25]. Another study reported that pigmented rice contains large amounts of medium polar or hydrophilic compounds such as phenolic, anthocyanins, proanthicyanidins and bioflavonoids shows anti-inflammatory activity in both *in vitro* and *in vivo* models (Ronchetti *et al*, 2009) [38]. Black rice is rich in cyanin-3-β-D-glucoside (C3G) and many studies reported the C3G possesses anti-inflammatory effects (Xia *et al*, 2006) [53].

7.5. Skin anti-ageing activity
Several studies have shown that bioactive compounds found in pigmented rice such as proanthocyandin, vanillic acid, catechin and γ-oryzanol, can be useful as skin anti-aging agents in the cosmetic and nutraceutical industries (Limtrakul

et al, 2019) [25]. Skin aging is a process caused by progressive physiological and structural changes in the skin. These variations associated with age, lifestyle, diet and sunlight may be considered as human intrinsic and extrinsic factors. In addition, some environmental factors can also lead to skin aging (Ganceviciene *et al*, 2012) [12]. It has been reported that pigmented rice has antioxidant properties, their extracts could be used for skin anti-aging purpose (Limtrakul *et al*, 2019) [25].

7..6 Anti-allergic activities
Black rice is widely known as enriched rice and has been used to treat various allergic disorders such as dermatitis and bronchitis in traditional medicine (Deng *et al*, 2013) [10]. For the study of anti-allergic activity of methanol extract of Oryza sativa L. subsp. hsien Ting (OSHT), a variety of black rice in china. In murine model, mast cells *in vivo* and *in vitro* were tested for inhibition of histamine release, local anahylaxis and systemic anaphylaxis after treatment with OSHT. The result showed that OSHT (0.001-1.0 mg/g BW) had dose-dependent inhibition against systematic anaphylaxis induced by compound 48/80. Local anaphylaxis active by antidinitrophenyl DNP IgE and serum histamine release in rats. In case of *in vitro*, OSHT was also inhibited the release of histamine from rat peritoneal mast cells activated by compound 48/80 or by anti-DNP IgE in a dose dependent manner (Kim *et al*, 1999) [20].

7.7 Anti-atherosclerosis activities
Several studies have reported that dietary supplementation of pigmented rice such as red or black instead of white rice has contributed in a significant increase in the concentration of high-density lipoprotein (HDL) and the glutathione peroxidise (GPx) activity in hyper-cholesterol rabbits, which corresponded to a decrease in the size of atherosclerotic lesions in that animals (Deng *et al*, 2013) [10]. In addition, supplementation of the black rice outer layer fraction to the rabbits significantly reduced aortic 8-hydroxy-2-deoxyguanosin (8-OHdG) and the malondildehyde (MDA) level of serum and aortic artery (Ling *et al*, 2001, Chen *et al*, 2000) [7]. Moreover, *in vivo*, supplementation of pigmented black rice effectively increased plasma total antioxidant capacity (TAC), and substantially reduced plasma levels of soluble vascular cell adhesion molecule-1, soluble CD40 ligandand high sensitive C-reactive protein, and exerted cardio protective effects on patients with coronary heart disease by improving plasma antioxidant status and inhibiting inflammatory factors (Wang *et al*, 2007) [51].

7.8 Anti-tumour activities
In our body, reactive oxygen species (ROS) are produced by some tumour promoter in the development of cancer. An *in vitro* studies using flow cytometry, 70% ethanol–water extracts of bran (outer layer) from seeds of five pigmented rice cultivars such as Jumlalocal-1, DZ 78, Elwee, LK1-3-6-12-1-1, and LK1A-2-12-1-1 revealed their antitumour-promoting activities by measuring the inhibition of Epstein-Barr virus early-antigen activation (EBV-EA) which was later induced by the tumour promoter 12-O-tetradecanoylphorbol-13-acetate (TPA). The results showed that pigmented varieties strongly inhibited phorbol ester-induced tumour promotion in marmoset lymphoblastoid cells B95-8 *in vitro* as compared to non-pigmented variety (Nam *et al*, 2005).

7.9 Alleviating gallstones
Women who consume foods rich in insoluble fibre, such as brown rice, have gained protection against gallstones. Furthermore the 17 percent decrease in gallstone in women was noted, particularly whose diets were incorporated with brown rice. 5g increase in insoluble fibre dropped risk by 10% (Babu *et al*, 2009) [4].

8. Conclusion
In this review we are mainly focusing on bioactive components and their health benefits of rice. Rice is one of the cereals considered as an important plant for the supply of staple food over half of the world’s population. It is considered as the source of carbohydrates and supplies energy to body through diet. India are rich in pigmented rice and major source of bioactive compounds like phenolic acid, flavones, anthocyanin etc. Extraction is the first step in the preparation of cosmetics, food ingredients, pharmaceutical products, nutraceuticals, and dietary supplements products using rice bioactive compounds. Before extraction of bioactive compounds, the rice is treated with various processing steps such as milling, grinding and homogenization, which maintain higher amount of bioactive compounds. Various extraction methods are used for extraction bioactive compounds from rice including traditional methods (like Soxhlet extraction method and maceration method) to modern methods (like accelerated solvent extraction method (ASE), solid-phase extraction (SPE), pressurized liquid extraction (PLE), pressurized fluid extraction (PFE), subcritical water extraction (SWE), subcritical fluid extraction (SFE), microwave-assisted extraction (MAE), vortex-assisted extraction (VAE), ultrasound-assisted extraction (UAE)) and their combinations. In the case of parboiled rice, the paddy is parboiled and dried before shelling and milling takes place. The processing steps are cleaning, parboiling, drying, dehusking, partial milling, grading, packing and storage. Coloured rice consumption is rich in beneficial bioactive compounds will help to promote some health benefits such as anti-oxidant activity, anti-cancer, anti-diabetic, Anti-inflammatory, skin anti-aging, anti-allergic, anti-atherosclerosis, anti-tumour, alleviating gallstones, lowers cholesterol etc.

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