**Mini Review**

**Brown Rice, a Diet Rich in Health Promoting Properties**

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**Summary**

As a staple food crop rice caters to the energy needs of more than 4 billion people around the globe. Since the 1980s, rice breeding focused on breeding for superior grain quality with good texture, taste, palatability and aroma. The recent rise in double burden nutrition challenges suggests that there is a pressing need to focus on incorporating nutritional traits also in rice breeding efforts. 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 glycemic index properties; hence they might be helpful to counter the growing type II diabetes. Colored rice varieties with red or purple pericarps are known to possess high levels of bioactive compounds such as cyanidin-3-glucoside, various flavonoids and γ-oryzanol. Germinated brown rice has more potential health benefits, for example, 10-fold of γ-aminobutyric acid than milled rice. For future nutritional intervention, we recommend further explorations into the nutritional value of brown rice as well as to modify the endosperm for enhanced nutrition without altering the texture to ensure consumer acceptance.

**Key Words**

brown rice, landraces, coloured rice, bioactive compounds, protein content

In the 1960s and 1970s, green revolution catalyzed the increased crop yield, leading to improving the economy in Asian countries such as Japan and Korea. This led to rice self-sufficiency. Since then the trend in rice breeding in several Asian countries such as Japan has targeted good grain quality to improve taste, texture and shiny appearance of milled white rice. For example, “Koshihikari” with outstanding grain quality developed by Japanese breeders became the most popular and highly grown Japonica variety in East Asian countries as well as Australia and United States (1).

In the 21st Century, more than 2 billion people suffer from mineral malnutrition, mainly iron (Fe) and zinc (Zn) deficiency. Also meta-studies link the high consumption of sugar rich processed food, including milled rice, and a stagnant life style to increased incidences of chronic diseases such as type II diabetes (2) leading to nearly 430 million sufferers. These issues are complicated by rice milling, which removes the aleurone layer rich in micronutrients, proteins and secondary metabolites (3). Therefore, diet diversification and changes in rice consumption is evident in Korea and Japan. Meats, vegetables or coloured fruits, high in antioxidants, are not affordable for low and middle income population. Hence, increasing proteins, micronutrients and other bioactive compounds in staple foods can be a better option for intervention to promote health.

**Brown Rice Components**

Compared to milled rice the benefits of brown rice are relatively high. One cup of cooked brown rice (195 g) on an average represents 216.4 calories of energy, 1.76 g fat, 0.64 g monounsaturated fat, 0.63 g polyunsaturated fat, 0.35 g saturated fat, 44.8 g of carbohydrate, 5.03 g protein, 0.66 g fiber, 0.19 mg thiamine (B1), 0.05 mg riboflavin, 2.98 mg nicotinic acid, 0.28 mg pantothenic acid, 0.28 mg vitamin B6, 7.80 mg folic acid, 19.50 mg calcium, 0.82 mg iron and 1.23 mg zinc. Brown rice is also a good source of selenium, manganese and magnesium (3, 4) which play important roles in prevention of various diseases such as colon cancer, type II diabetes and asthma (2, 5–7). Vitamin E composed of eight lipid homologues: α-, β-, γ-, δ-tocopherol/tocotrienol highly occurs in brown rice and known to scavenge lipid peroxyl radicals, thus reduced cellular ageing (8–10). Lee et al. (11) suggested that the specific ratio of homologues rather than total vitamin E content, i.e. high γ-tocotrienol proportion relative to α-tocopherol, efficiently reduces damage to lipid membranes.

**Landraces and Coloured Rice Possess Bioactive Human Health Promoting Substances**

Landraces are consumed as brown rice by many tribal populations, and people living in upland areas. Milled rice contains 90% carbohydrates composed of amylose and amylopectin (12). Diabetic patients should therefore avoid taking milled rice since it can raise blood glucose very quickly (high glycemic index). In certain landraces like Aklan/Philippines, starch digestion has been

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reported to be slow (13), hence those varieties could be recommended for diabetic patients. This highlights that selected landraces may possess superior nutritional targets as compared with modern varieties. Using the advanced metabolomics pipeline by ultra performance liquid chromatography-mass spectrometry (UPLC-MS) (14), scientists at the International Rice Research Institute (IRRI) have profiled nutritional properties of traditional landraces. Through systems genetics approach using a diverse landraces panel, Butardo et al. (15) identified one genetic region on chromosome 7 which elevated the proportion of amylose at the expense of reduced short-chain amyllopectin, thus potentially influencing reduced digestibility.

Landraces have considerable variation in the colour of the pericarp. Red and purple (or black) pericarps, which are controlled by Rc (bHLH transcription factor regulating proanthocyanidin production) and Rd (dihydrolavonol-4-reductase) genes (16–17), contain high levels of bioactive secondary metabolic compounds (18). For example, cyanidin-3-glucoside (C3G) rich in Korean purple rice showed a higher antioxidant capacity (19) and also inhibited the growth of human leukemia cells (20). Lee et al. (21) reported high contents of phenolic compounds and γ-oryzanol in a coloured rice panel held at IRRI. γ-oryzanol is one of the strongest antioxidants present in rice bran, which could be extracted along with bran oil. γ-oryzanol is also known to inhibit LDL-cholesterol synthesis (22). In China, red yeast rice is being used as both food and medicine. It is helpful to promote blood circulation, soothe upset stomach, as a supplement to bruised muscles and to invigorate the function of spleen (23). Landraces and coloured rice varieties will be useful in future breeding programs aimed at adding valuable health promoting properties in high yielding lines.

**Treatments Increasing Bioactive Compounds**

In several tribal districts in India, e.g. Assam, Bihar, Chhattisgarh, and Jharkhand areas, people parboil the rice before milling (23). Milled parboiled rice contains 2–4 times higher thiamine, niacin and riboflavin than the raw rice (24). This is due to driving of these vitamins into the endosperm from the bran and by gelatinizing the starch of the outer layers which seals the aleurone layer and the scutellum (23) and possibly reduces the glycemic index.

Germinated brown rice (GBR) has been found to contain reduced insoluble phenolic compounds but increased free phenolic acids (25). In addition, two new compounds, namely 6′-O-(E)-feruloylsucrose and 6′-O-(E)-sinapylsucrose isolated from GBR may have potential health benefits (25). GBR also inhibits prolidopeptidase activity and this may lead to possible prevention of Alzheimer’s disease (26). When nutrient values of GBR were compared with milled rice, γ-aminobutyric acid (GABA) increased by 10-folds, magnesium 3 to 4-folds, vitamin E and dietary fiber 4-folds, and calcium by 1.5-folds (27).

**Future Direction: Improving Total Protein Content**

Rice is an important source of protein, especially in developing countries where the meat consumption rate is very low. However, the protein content in rice grain is relatively lower than other crop species like beans. Furthermore, rice does not have a full amino acid profile, in particular lysine (28). Various studies have been conducted to increase the lysine content in rice grains. Through genetic modification (GM) approach, Liu et al. (29) expressed a LYSINE-RICH PROTEIN gene from *Psophocarpus tetragonolobus* (L.) DC using an endosperm-specific GLUTELIN1 promoter and this resulted in 30% increased lysine level in rice grains.

As the Recommended Dietary Allowance (RDA) for protein is a modest 0.8 grams of protein per kilogram of body weight (30), more breeding efforts are needed to increase total protein content in rice grains. However, the genetic basis of variation in total protein content is still not completely understood. Peng et al. (31) reported the cloning of the OsAAP6, an amino acid transporter which functions as a positive regulator of total protein content in grains. Through genome-wide association study (GWAS) combined with quantitative real-time PCR, Chen et al. (32) identified several grain-quality-related and starch-metabolism-related genes associated with major proteins. A more comprehensive analysis such as subpopulation-specific (as considering intraspecific variation in genomic structure in rice) phenotyping and functional genomics is necessary for further studies in order to have an influence on rapid breeding process maximizing the nutritional values in brown rice.

Since not all rice is the same with respect to its nutritional benefits, it is imperative to understand the vast rice diversity of 120,000 accessions stored in gene bank. With the availability of advancement of technologies such as GC-MS/MS, LC-MS/MS, LC-TOF, UPLC-MS/MS, we can undertake the fingerprinting of nutritional bioactive compounds present in rice bran across diversity lines. Combining high-throughput metabolomics approaches with systems-genetics approaches will help to identify key candidate genes influencing multiple nutritional targets. These integrative approaches, together with employing precision breeding techniques will help to diversify the nutritional needs in staple crop to promote future health benefits and to address double nutritional burden challenges.

**Disclosure of State of COI**

No conflicts of interest to be declared.

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