Journal of Plant Studies; Vol. 9, No. 1; 2020
ISSN 1927-0461 E-ISSN 1927-047X
Published by Canadian Center of Science and Education

Characteristics of Giant Embryo Rice and Research Prospect of Its Processing and Utilization

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Received: November 9, 2019 Accepted: December 6, 2019 Online Published: December 17, 2019

doi:10.5539/jps.v9n1p13 URL: https://doi.org/10.5539/jps.v9n1p13

Abstract

Giant embryo rice is a special kind of functional rice which can produce eutrophic rice. It conforms to people's concept of food consumption and healthy life. Giant embryo rice and its intensively processed products have been widely used in food, medicine, health products and other fields. They have extremely important scientific significance and economic value, and have become one of the most nutritional and health-care functional rice in the future. In recent years, a series of important advances have been made in the research of giant embryo rice. The special nutrients, agronomic characteristics and products developed by giant embryo rice have attracted the attention of rice breeders and consumers at home and abroad. In this paper, the research contents and new advances in the creation and breeding of giant embryo rice germplasm, the characteristics of nutrient changes, important agronomic traits and the processing and utilization of giant embryo rice were summarized, and the application prospect of giant embryo rice was prospected, all of which could provide important reference for the development and sustainable utilization of giant embryo rice.

Keywords: giant embryo rice, processing and utilization, agronomic characters, nutrients

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops in the world. More than half of the world's population lives on rice, which provides more than 25% of its energy needs (Kusano et al., 2015; Peng et al., 2019). With the sustained development of the global economy and the continuous improvement of people's living standards, In terms of food demand, it has changed from satiety in the past to safety, pollution-free and nutritional health in the now (Zhou et al., 2009). Giant embryo rice is a kind of rice which can produce high nutritional functional rice in special rice. Compared with ordinary rice, the volume of embryo from giant embryo rice increases about 2-3 times. The content of protein, mineral and vitamin is higher than that of ordinary rice. It has higher antioxidant activity and better nutritional and health functions. In addition, large amounts of oryzanol and GABA are found in giant embryo rice, which have anti-cancer and anti-hyperlipidemia functions (Zhang et al., 2005; Seo et al., 2011; Fitzgerald et al., 2003; Kang et al., 2011). Because giant embryo rice is consistent with people's current food consumption concept and healthy life concept, it has become one of the most competitive nutritive rice in the future, which has attracted the attention of rice genetic and breeding experts at home and abroad in recent years.

Over the past decades, many research groups at home and abroad have conducted in-depth theoretical research on giant embryo rice, and made a series of important new progress. At the same time, in the application of giant embryo rice, the new varieties bred have been initially promoted, some new varieties of giant embryo rice have entered the market, and the related products of its deep-processing have been widely used in many fields such as health care, food, medicine and so on. Especially in the field of medical treatment and health care, the processing products of giant embryo rice are playing an increasingly important role, which shows that the products related to the deep-processing of giant embryo rice have important value and broad application prospects. This paper focuses on the quality characters, important agronomic characters, product processing and utilization, genetic basis and improvement strategies of giant embryo rice were summarized and analyzed, and its application prospects were prospected, in order to provide reference for genetic improvement and application promotion of giant embryo rice.

2. Create and Breeding of Rice Giant Embryo Germplasm

Physical or chemical methods can induce corresponding mutations in normal rice seeds, and then select giant embryo rice. Japanese rice breeders used chemical mutagen N-methyl-N-nitrosourea (MUN) to treat the seed cells of rice variety Kinmaze, and then obtained the giant embryo mutant rice (Satoh et al., 1981). Through in-depth genetic analysis, the gene controlling giant embryo was located on chromosome 7 of rice, which is called giant embryo gene (*Ge*) (Satoh et al., 1990). Korean rice breeders also used N-methyl-N-nitrosourea chemical mutagen to treat the fertilized immature embryos of Japonica rice Hwacheongbyeo, induced a series of giant embryo mutant rice, and obtained the germplasm of giant embryo Japonica rice (Kim et al., 1991), It’s molecular mapping showed that the gene controlling giant embryo was also located on chromosome 7 and Alleles at the same point as the giant embryo gene Ge (Kim et al., 1992; Koh et al., 1996). A large number of giant embryo rice varieties, such as Haiminori, Mebaemochi, Koiazusa and Haiibuki, were bred by crossing the giant embryo mutant EM40 of Kinmaze with the high-yield variety Akenohoshi（Endo et al., 2006; Ishii et al., 2013; Matsushita et al., 2008; Maeda et al., 2001; Uehara et al., 2003）, These giant embryo rice are widely planted as functional rice. Using radiation mutation breeding technology, giant embryo rice can also be produced (Zhang et al., 2003; Li et al., 2004). Seeds of restoring line Minghui 86 were irradiated by Co-60-gamma rays (Zhang et al., 2009a). Only one rice mutant seed with giant embryo trait was obtained from about 344,800 rice seeds of M2 generation, named giant embryo Ming86, indicating that the probability of mutation to giant embryo rice mutant by radiation was low.

In order to select *indica* giant embryo rice varieties suitable for direct cultivation in southern rice region, The *indica* giant embryo intermediate breeding material "80096" crossed between "91-308" and "giant embryo 2" was used as the donor parent of giant embryo gene and crossed with the restoring line "Xianhui 207"， and a new indica giant embryo rice variety Ganju 1 was bred by multiple generations of selfing (Zhang et al., 2016). The embryonic tissues of normal rice "Chao 2-10" were cultured in vitro. A single gene mutation resulted in a new giant embryonic rice variety "Shangshida 5" (Ren et al., 2011). Further studies showed that the content of vitamin E in brown rice of "Shangshida 5" giant embryo rice was significantly higher than that ocontrast rice "Chao 2-10" (Wang et al., 2013). It implies that the nutritional value of the giant embryo rice No. 5 of Shangshida 5 is higher. Haiminori is a giant-embryo Japonica Rice Variety originating in Japan, as the female parent hybridization with Xiushui 110, the main rice cultivar in Shanghai, as the male parent, and successive selection of offspring resulted in a fine giant embryo Japonica rice line “*Japonica* rice of Shangshi 315”. The red polished round-grained rice line S134, which was bred from the hybrid progenies of "Abo-red rice" and "Xiushui 128", was used as the male parent and crossed with " Japonica rice of Shangshi 315", Finally, a new early-maturing functional rice line "Giant Embryo Red *Japonica* Rice 1" was bred (Lin et al., 2014), The main characteristics of this line are high yield, large embryo, red brown rice, rich in anthocyanins and high nutritional value.

Oil of rice bran is a by-product of rice processing. It can provide many health effects for human beings and contains more unsaturated fatty acids. Interestingly, in order to increase the content of triacylglycerol in rice bran, N-methyl-N-nitrourea was used to treat the developing seed cells of high-yielding rice variety Mizuhochikara (Mitsukazu et al., 2016), After screening the seeds of M2 mutant, four giant embryo mutants were obtained, which could significantly increase the oil content in rice bran, which provided a new breeding strategy for the cultivation of new functional rice varieties. With the increasing potential demand for giant embryo rice, the breeding of new giant embryo rice varieties has developed rapidly in recent years, and a number of new giant embryo rice varieties with important application value have been bred successively. Therefore, through the strategy of combining chemical or physical mutagenesis with traditional hybrid breeding, and dressing by screening of hybrid offspring, the nutritional function of rice can be adjusted, and new functional giant embryo rice varieties can be bred.

3. Characteristics of Nutrients in the Seeds of Giant Embryo Rice

The main nutrients in rice seeds include starch, storage proteins, amino acids and lipids. In addition, there are a few micronutrients such as vitamins and minerals in the seeds. Their composition and relative content have important effects on the quality of rice and are closely related to human nutrition and health (Peng et al., 2018). Compared with common cultivated rice, the contents of 17 kinds of amino acids in giant embryo rice increased significantly, the total amino acids increased by 4.77%-37.09%, and the total essential amino acids increased by 2.52%-35.62%. Meanwhile, the contents of mineral elements in the seeds of giant embryo rice were more abundant and diversified, and the content of GABA in brown rice increased significantly, with an average increase of 286.58% (Zhang et al., 2009b). It is noteworthy that the relative embryo weight of giant embryo rice is positively correlated with the content of most nutrients (Yan et al., 2013). If the relative embryo weight of rice seeds is increased, the content of nutrients in rice seeds will be increased, and the nutritional value of rice will be increased finally. The content of GABA in brown rice increased by 150%, 400% and 850% respectively with the increase of embryo size in giant embryo mutant ($le < ge < ge^s$). The contents of other nutrients such as protein, lipid, vitamin B1 and vitamin E also increased (Koh et al., 1993; Kim et al., 2013; Chung et al., 2014). However, there are some exceptions. Although the amylose content in the seeds of the giant embryo rice variety "Suweon 542" from Korea is significantly higher than that of the wild type, its protein content is significantly lower than that of the wild type control variety (Mo et al., 2013). In the giant embryo black glutinous rice induced by Ge gene mutation, it was found that the total protein content, fat content and amino acid content in brown rice increased to a certain extent, and the increase was mainly related to the size of embryo (Sang et al., 2012). Further studies showed that the contents of protein, polyphenol crude extract and amino acid in rice bran of giant embryo black glutinous rice increased significantly, especially the content of GABA increased 10.6 times than that of brown rice, and amylopectin and anthocyanin were enriched in brown rice and rice bran. The early-maturing Japonica rice variety "Giant Embryo Red *Japonica* Rice 1" has the characteristics of high yield, gigantic embryo, brown rice red and high anthocyanin content. Compared with common rice varieties, the contents of gamma-aminobutyric acid and vitamin E in the seeds of Giant Embryo Red Japonica Rice 1 increased significantly (Dong et al., 2014). By means of non-targeted metabonomics analysis, the metabolites in embryonic rice of giant embryo rice "Shangshida 5" and common cultivated rice "Chao 2-10" were compared. It was found that the content of beta-alanine in " Shangshida 5" was 18.71 times higher than that in "Chao 2-10" (Guo et al., 2019). The contents of 8 vitamin E homologues in brown rice, endosperm of common cultivated rice and "Shangshida 5" were determined by high performance liquid chromatography. Quantitative RT-PCR analysis showed that the content of vitamin E in brown rice of "Shangshida 5" was about 2.2 times of that of "Chao 2-10" (Wang et al., 2013). Therefore, the embryo body of giant embryo rice seeds increased, and the contents of protein, minerals, anthocyanins and vitamins in rice were higher than those in common rice. It is a high nutritional functional rice with higher nutritional and health functions. Interestingly, a large amount of oryzanol and GABA were found in giant embryo rice. They have anti-cancer and anti-hyperlipidemia effects. They are in line with people's food consumption and health concepts and have broad application prospects.

After germination, the nutrient distribution of giant embryo rice changed sharply, and germination could improve the nutrient content of brown rice (Zhang et al., 2005; Cho et al., 2016). Soaking whole grain rice for several days until radicle length is about 2 to 5 mm, this process will cause a series of biochemical changes such as activation of various enzymes and release of free conjugates, resulting in softening of brown rice texture, increase of bioactive compounds and increase of bioavailability of biological nutrients (Moongngarm et al., 2010; Patil et al., 2011). Studies have shown that germination can significantly increase the contents of GABA, γ-oryzanol and tocopherol in brown rice (Cho et al., 2016; Ng et al., 2013). During the germination of rice seeds, the GABA content in giant embryo rice seeds was higher than that in common rice varieties. The GABA content in giant embryo rice seeds reached the maximum at 45 h of germination, reaching 617 mg kg-1 (Zhang et al., 2013). giant embryo rice giant embryo rice. By analyzing the expression level of GABA metabolic gene and the content of GABA metabolic intermediates in the developing grains and germinated brown rice of giant embryo rice "Shangshida 5" and control rice "Chao 2-10", it was found that genes related to polyamine pathway and GABA catabolism played an important role in GABA accumulation in giant embryo rice seeds (Zhao et al., 2017). Therefore, the germination of brown rice of giant embryo rice can improve its nutrient content, contribute to nutritional balance and nutrient transformation and absorption.

Amylose content is the main factor affecting the gelatinization properties of rice. Lipid content and amylopectin properties also affect the gelatinization and viscosity of rice to a certain extent. With the increase of amylopectin length ratio in rice, the gelatinization temperature will increase (Araki et al., 2009; Heo et al., 2012). The endosperm of the giant embryo rice mutant "Suweon 542" is silky with a white opaque appearance. Cross-sectional observation of the desquamated endosperm shows that most of its endosperm is white opaque. Further observation by scanning electron microscopy showed that the starch granules were loose and irregular round, and the flour photometry was significantly higher than that of wild type varieties (Mo et al., 2013). At the same time, it was found that the gelatinization temperature of rice flour with smaller grain size of giant embryo rice mutant was higher and its gelatinization parameters increased (Lee et al., 2013). Studies have shown that there are no significant differences in amylose content, alkali extinction value, gel consistency and gelatinization temperature of physicochemical properties between giant embryo rice mutant and wild type rice (Zhang et al., 2007). However, some studies have shown that gelatinization temperature and viscosity values of giant embryo rice samples are generally higher than those of common rice (Soo, et al., 2016; Kang et al., 2006). This may be due to the different genetic background of giant embryo rice. The specific relationship between the gelatinization temperature and viscosity value of giant embryo rice and common rice needs further study.

4. Characteristics of Important Agronomic Characters of Giant Embryo Rice

Studies on genetic variation of giant embryo rice showed that diploid genetic variation could improve agronomic traits of giant embryo rice, but aneuploidy might hinder the increase of giant embryo rice yield (Burner et al., 1991). The processing quality of rice is mainly affected by the mutation from normal embryo to giant embryo. Comparing 9 agronomic traits and 5 yield-related traits of "Chao 2-10" and "Shangshida 5", it was found that there was no significant difference between other traits except 1000-grain weight (Ren et al., 2011). The results of analysis of *indica* giant embryo rice obtained by radiation mutagenesis showed that the main agronomic traits, such as effective panicle number, grain number per panicle and seed setting rate, were not significantly different from those of the control group, but the 1000-grain weight of giant embryo rice decreased (Zhang et al., 2007a). Although the 1000-grain weight of giant embryo rice decreased, the absolute embryo weight and relative embryo weight of giant embryo rice increased significantly compared with the control varieties (Table 1) (Zhang et al., 2007a; Zhang et al., 2014). This may be due to the increase of the embryo weight of giant embryo rice, which requires more energy to accumulate nutrients in the embryo, thus reducing starch accumulation. By comparing the hybrid giant embryo rice and radiation mutagenesis giant embryo rice, there are also large variations in the main agronomic traits (Lin et al., 2013). Major agronomic traits and yield-related traits of giant embryo rice "Suweon 542" and wild type control varieties were investigated (Mo et al., 2013). It was found that the heading date of "Suweon 542" was 3 days later than that of wild type, plant height was 6 cm higher than that of wild type, ear length had no significant difference, grain maturity rate was low, grain weight was low, and the number of per panicle of "Suweon 542" are increased significantly. Therefore, giant embryo rice is richer in nutrients than common cultivated rice, but its yield will decrease slightly. There are also some differences in agronomic traits of giant embryo rice varieties bred by different ways.

In order to further explore the reasons of the giant embryo rice grain weight, the Richards equation of two giant embryo rice and its corresponding control varieties (Long Pu B, 1813 B) the grain-filling process fitting, the result shows that the giant embryo rice in the initial grouting rate, average filling rate and maximum grouting rate and filling duration which is lower than control varieties, and the giant embryo rice in 4~12 d after flowering grouting during the peak filling rate was lower than that of control varieties, eventually led to the decrease of the grain weight of giant embryo rice (Zhang et al., 2016). Select 57 grain shape differences of *indica* strain of giant embryo rice and *indica* non-giant embryo strains, the brown rice of the absolute embryo weight and relative embryo weight and grain length, grain width, grain thickness, length-width ratio and grain weight, grain shape traits related analysis (Zhang et al., 2006), the results showed that the embryo weight of giant embryo rice and grain length, grain width, grain thickness and there is significant correlation between grain weight, namely choose smaller grain weight and grain length is shorter and moderate thick grain of grain shape can improve the relative embryo weight of giant embryo rice, relative embryo weight of common cultivated rice is significantly affected by grain length, grain width, grain thickness to length-width ratio.

By making paraffin sections on the longitudinal section of giant embryo rice embryo and observing the development process of giant embryo rice embryo character with microscope, we can find that the growth of giant embryo rice embryo mainly concentrates on 1-12 days after flowering, and the growth of giant embryo rice embryo is the fastest in 6-9 days. The embryos of giant embryo rice in each stage are larger than those of control varieties (Figure 1) (Zhang et al., 2008; Lee et al., 2019). From the cell number of embryo longitudinal section, there was no significant difference between mega-embryo rice and control varieties, indicating that the increase of giant embryo rice embryo was mainly caused by the volume increase of scutellum cells of embryo (Zhang et al., 2008). Interestingly, using the method of paraffin section observation during the same period of giant embryo rice embryo growth dynamics, the results show that the embryos of giant embryo rice are larger than those of common cultivated rice, and the number of cells in the embryo site of giant embryo rice is more than that of control rice, At the same time, the number of scutellum cells is larger than that of common cultivated rice, that is, the increase of giant embryo rice embryo is due to the increased of scutellum cell number and the increase of cell volume as a result (Du et al., 2016). Therefore, a large number of giant embryo rice samples need to be further collected for in-depth observation and Study on the specific causes of giant embryo rice embryo enlargement.

Table 1. Comparison of embryo traits between blastocyst rice and conventional non-blastocyst rice (Zhang et al., 2014)

Varieties	Embryo length /mm	Embryo width /mm	Absolute embryo weight /mg	Relative embryo weight /%
91-308	1.48	0.66	0.32	1.47
Xianhui 207	1.38	0.72	0.27	1.45
Giant embryo rice No. 1	2.69	1.68	1.16	6.02
Giant embryo rice No. 2	2.80	1.69	1.29	5.55
Liantang Red Giant Embryo rice	2.20	1.36	0.99	6.29
Ganju No. 1	2.26	1.38	1.09	6.44

Figure 1. Grain and embryo phenotypes of HC and giant embryo mutants

Images from left to right are of HC, *le*, *ge*, and ge^s in this order. Scale bars = 2 mm (Lee et al., 2019)

5. Processing and Utilization of Giant Embryo Rice

Brown rice is the caryopsis of rice after husk removal, which retains the embryo and seed coat of rice, while embryo and seed coat are enriched with more than 64% of micronutrients, physiological active substances (such as GABA, inositol, oryzanol, VE, glutathione and dietary fiber) and functional factors of physiological effects (such as vitamin, iron and zinc) (Chen et al., 2005). Some studies have shown that the main nutrient content of giant embryo brown rice is higher than that of ordinary brown rice, which is more in line with the healthy dietary needs of modern people. In addition, germination is an effective and inexpensive process to improve nutrient content and taste quality of giant embryo brown rice. After soaking, giant embryo brown rice can germinate, and the process of germination can significantly increase the content of GABA and other active substances in giant embryo brown rice (Wu et al., 2013). GABA is an inhibitory neurotransmitter in the brain and spinal cord of mammals. It has many functions such as brain strengthening, blood pressure lowering and calming (Yu et al., 2010). Germinated brown rice is rich in GABA, dietary fiber, inositol phosphate, oryzanol and other physiological active ingredients, which can reduce the incidence of cardiovascular and cerebrovascular diseases, prevent digestive tract tumors, anti-aging and many other health functions and pharmacological functions (Zhang et al., 2013). The brown rice of giant embryo rice is a kind of good functional health food. However, due to its poor taste and insufficient understanding of its nutritional value, the development of giant embryo rice as commercial rice is still hindered. The process of germination can greatly improve the nutrient content and taste quality of giant embryo brown rice. Therefore, the use of germination may break the current dilemma of the development of giant embryo brown rice and make it a popular health food.

There are many kinds of common colored rice, such as red, green, yellow, purple, black, cyan and so on. At present, colored giant embryo rice only cultivates red and black purple, and the different colors of seed coat are caused by the anthocyanin deposited on it. As a special kind of giant embryo brown rice, colored giant embryo rice has the nutritional quality of ordinary giant embryo brown rice. Besides, anthocyanins rich in its seed coat also have many functions such as antioxidant, antihypertensive, hypolipidemic, anti-inflammatory and anti-infection, improving liver function damage, preventing and treating cancer, protecting eyesight and so on (Lin et al., 2014). Therefore, colored giant embryo rice is also a kind of better functional health food. Important progress has been made in the cultivation of colored giant embryo rice. Various varieties (or strains) of colored giant embryo rice have been developed by rice breeding experts at home and abroad. For example, by crossing giant embryo rice germplasm "Giant Embryo 1" with red rice indica rice variety "91-308", a new red rice indica giant embryo rice line "Liantang Giant Embryo Red" was successfully bred. It not only retains the fine quality and high mineral element content of indica red rice, but also has giant embryo, rich in iron and GABA, ingredients can be used as functional rice to reduce blood pressure (Zhang et al., 2012). The results of multi-point experiments showed that the "Liantang Giant Embryo Red" strain had the characteristics of strong tillering ability, moderate growth period, large embryo and stable yield (Zhang et al., 2012; Zhong et al., 2013). "Shangshi Japonica Rice 315" as the female parent and red japonica rice hybrid strains "S134" as the male parent, in the offspring breeding new strains of functional rice " Giant Embryo Red Japonica Rice 1", a variety of nutrients were significantly better than contrast varieties, especially GABA and VE content more than five times higher than in control and 2 times respectively (Lin et al., 2014). A new lines of black fragrant type giant embryo rice, "2013-2207" and "2013-2305" were successfully selected by hybridizing the fragrant type giant embryo rice with black non-fragrant normal giant embryo waxy rice line "Shangshi Black Waxy" (Cai et al., 2014). Red rice "Shangshida 6" and white rice giant embryo rice "Shangshida 5" were crossed, and a new japonica red rice giant embryo rice line "Shangshida 10" (Wang et al., 2017) was bred. The line has the characteristics of early maturity and high yield, showing a good market prospect. South Korean rice breeders have also successively bred black glutinous giant embryo rice variety "Milyang 263" and purple giant embryo rice "Keunnunjami" (Han et al., 2012; Park et al., 2010). Among the colored giant rice cultivated by breeding experts at home and abroad, some varieties of colored giant rice have been widely used and popularized. These functional giant embryo rice are favored by consumers, because of their multiple nutritional and health functions.

Giant embryo rice as a functional rice with high nutrition, but influenced and restricted by rice processing technology, in the process of processing giant embryo rice into giant embryo rice, a large number of by-products with low added value, such as broken rice, rice bran and rice husk, are produced. How to effectively utilize these by-products and transform them into products with high added value is an important problem to be solved urgently at present. It is gratifying to note that experts and scholars at home and abroad have carried out a series of experiments and explorations on this issue, and put forward innovative solutions. On the efficient utilization of broken rice from giant embryo rice, some experts put forward the plan of preparing ready-to-eat breakfast of broken rice by extrusion method. This kind of breakfast has the characteristics of good texture, high nutritional value and good protein quality（Boon et al., 1999）. In the broken rice of giant embryo rice, there are both endosperm and rice embryo. They are rich in starch, amino acids, vitamins and proteins and other nutrients. They are a valuable resource for deep processing. In addition to directly utilizing the broken rice of giant embryo rice, extracting nutrients from the broken rice of giant embryo rice is also an important means to improve the added value of giant embryo rice. For example, rice germ oil is a kind of high-quality functional oil extracted from rice embryo. Its ratio of oleic acid to linoleic acid is close to ideal 1:1. Rice embryo in broken rice from giant embryo rice crushed rice contains a lot of lipid, which is about twice the lipid content in ordinary rice embryo (Jin et al., 2016). Therefore, is an ideal material for extracting rice germ oil. Broken rice from giant embryo rice is rich in not only lipid but also high-quality storage protein (Zhao et al., 2012; Zhu et al., 2018). The amino acid composition of stored protein in rice is reasonable, and its biological value is high. Especially the lysine content is the highest in cereals (Li et al., 2016). It is the only grain protein that can be free from allergy test. It can be used as protein nutritional raw material for infant food. It has great application value and broad market prospect.

The endosperm of broken rice from giant embryo rice contains a large amount of starch, which can be used as raw material for extracting fructose. Because fructose is not easy to cause blood sugar rise, fat accumulation and obesity, it is widely used in food, medicine, health products and other fields (Wu et al., 2013). Proteins in broken rice of giant embryo rice can also be used as raw materials for extracting angiotensin converting enzyme (ACE) inhibitory peptide, which greatly improves the utilization rate of broken rice of giant embryo rice (Zhang et al., 2016; Mara et al., 2019). Using fermentation or enzymatic hydrolysis technology, the crushed rice of giant embryo rice can be made into nutritious rice milk and yoghurt (Zou et al., 2018; Zhu et al., 2018), and the broken rice of giant embryo rice can also be ground directly to make high nutritive rice powder as infant rice powder or other food additives. In the efficient utilization of broken rice from giant embryo rice, we can not only draw lessons from the processing methods of ordinary broken rice, but also according to the characteristics of broken rice from giant embryo rice itself rich in a variety of nutrients, weed out the old and bring forth the new, and develop the characteristic intensive processing products.

Rice bran is a by-product of brown rice polishing. It is rich in protein, fat, dietary fiber vitamins and minerals, such as iron, potassium, calcium, chlorine, magnesium and manganese. Rice bran has high lipase activity after processing, which makes rice bran oil hydrolyzed into free fatty acid. Therefore, most industries use high temperature heat treatment to inactivate lipase, but high temperature has adverse effects on the separation of rice bran protein and its functional properties. Inhibiting lipase activity by chemical and low temperature treatment can prevent the hydrolysis of rice bran lipid and make rice bran have longer shelf life, which lays a foundation for extracting protein from rice bran, rice bran oil and other intensive products (Singh et al., 2016). Rice bran oil is a new kind of edible oil obtained by pressing and refining rice bran. Its unsaturated fatty acid content can reach more than 80%, and it is rich in oryzanol, phytosterol, vitamin E, squalene and other bioactive ingredients. It is called "healthy nutrient oil" (Ye et al., 2019). The nutritional properties of rice bran oil can be widely used in food, health products and feed industries. It can also be used to produce energy and chemical products such as biodiesel or plasticizer of excellent polymer (Gao et al., 2012; Zuo et al., 2019). Because ordinary rice bran can not meet the demand of extracting rice bran oil, a high-oil mutant of giant embryo rice was developed to meet the huge demand for rice bran oil (Mitsukazu et al., 2016). Albumin, globulin, glutenin and gliadin are the main residues of rice bran oil extracted from rice bran, which are very close to soybean protein components. Protein in rice bran is a very important nutrient, and the protein content in giant embryo rice bran is more abundant, which is very suitable for extracting rice bran protein (Zhang et al., 2009). The essential amino acids in rice bran protein are complete and easy to digest compared with other plant proteins. Another obvious advantage of rice bran protein is that it has the same hypoallergenic as rice embryo protein. It is the lowest allergenic protein known in grains and can play an anti-cancer role (Xing et al., 2019). Enzyme-assisted to preparation rice bran protein concentrate can not only be used as raw materials for food and health products, but also extract other active substances from it. In vitro digestion method (pepsin - trypsin system) hydrolyzed concentrated rice bran protein, which can obtain antioxidant peptides with molecular weight of 800~2100, greatly improving the antioxidant properties of rice bran protein (Ladda et al., 2016; Phongthai et al., 2018; Thamnarathip et al., 2016). Therefore, rice bran protein hydrolyzed by digestion in vitro can be used as a natural food antioxidant and has important application value. In addition, the use of cysteine proteinase inhibitors can promote the efficient release of rice bran protein (Udenigwe et al., 2015), which can be used to treat hypertension, oxidative stress, Ⅱ diabetes and other abnormal cellular response of active substances. In addition to extracting rice bran oil and rice bran protein, rice bran can also extract other active substances, such as rice bran polysaccharide extracted from rice bran, which has many active functions such as anti-cancer, hypoglycemia, cholesterol lowering, anti-bacterial infection and enhancing immunity (Xing et al., 2019); The extracted octadecanoyl has the effect of anti-fatigue (Yan et al., 2012); Rice bran enzyme extract from rice bran has many effects such as reducing blood lipid, antioxidant, anti-inflammatory and anti-apoptotic (Perez et al., 2017); Ferulic acid extracted from rice bran has many physiological functions, such as anti-thrombosis, anti-oxidation, anti-mutation, anti-bacterial and anti-inflammatory, lowering blood lipid, preventing and treating coronary heart disease, and has a wide range of applications in medicine and food industry (Lu et al., 2018; Kumar et al., 2014). Therefore, rice bran of giant embryo rice is a "material treasure house". The intensive processing of rice bran can not only obtain a variety of health products beneficial to human body, but also obtain important raw materials for the production of other food, medicine and chemical products.

Rice husk has no obvious application value in the food and drug industry compared with the by-products of giant embryo rice such as broken rice and rice bran with higher nutrition. However, the combustible composition of rice husk is up to 70%, with very low sulfur content, and it also contains 60%-95% SiO_2 (An et al., 2011). Therefore, rice husk has wide application value in energy industry and material engineering. Through pyrolytic liquefaction technology, rice husk can be pyrolyzed into solid biological coke, which can realize efficient utilization of rice husk (Li et al., 2016; Maiti et al., 2006). Rice husk can be processed into a low-cost biological adsorbent of heavy metals and dyes (Chuah et al., 2005). Activated carbon with high specific surface area can be made by activating carbonized rice husk with potassium hydroxide as an activator (Peng et al., 2000). The high content of SiO_2 in rice husk is an important source of silicon-based materials. After acid treatment and calcination of rice husk, nano-silica particles (Athinarayanan et al., 2015) with many potential applications can be obtained. Microwave-assisted acid dissolution can effectively remove metal ions from rice husk, and can be used as a carrier of porous silica materials for catalysts (Ana et al., 2018). Amorphous silica nanowires can be prepared on a large scale by Fe_2O_3-assisted hydrothermal method. It plays an important role in the function and integration of nanoelectronics and nano-optoelectronic devices (Bathla et al., 2018). Rice husk ash formed by calcination of rice husk can also be used as an important raw material for superhydrophobic coatings and modified acrylic water-based coatings (Lin et al., 2019; Junaidi et al., 2016). Therefore, through in-depth study on rice husk processing and utilization, it was found that rice husk, broken rice and rice bran of giant embryo rice are important biomass resources and industrial raw materials, and have broad application value.

6. Prospects

With the development of economy and society and the continuous improvement of living standards, people pay more and more attention to their own nutrition and health status. Green, nutritious and safe food is favored by the majority of consumers. Giant embryo rice is a "pure natural" green food with wide adaptability and high safety, which is more acceptable to consumers. As a part of people's daily diet, giant embryo rice has many incomparable advantages in promoting people's nutrition and health. In the future, the breeding orientation and consumption market of giant embryo rice will mainly be oriented to three groups of people: the first group is malnourished people, whose intake of nutrients is insufficient or uneven, resulting in physical development and normal metabolism being hindered. Giant embryo rice is rich in many kinds of amino acids and nutrients necessary for human body. Faced with this kind of consumer population, we should cultivate new giant embryo rice varieties with high nutrients and relatively balanced nutrients, or new giant embryo rice varieties with specific nutrients. The second group is the overnutrition people, which has excessive intake of nutrients, and now the pace of life is faster, diet is irregular, leading to the occurrence of various chronic diseases. Giant embryo rice is rich in physiological active factors and has good preventive and therapeutic effects on various chronic diseases. With the increasing number of patients with chronic diseases, cultivating giant embryo rice with abundant special physiological active factors and extracting active factors through intensive processing will be the main direction of future development of giant embryo rice. The third group is the general consumer group, which has no special requirements for rice. The nutritional and health functions, appearance quality, cooking and eating quality of giant embryo rice are the main factors attracting ordinary consumers. Although many new giant embryo rice varieties have been bred by rice breeders at home and abroad, their market share still needs to be improved. This is mainly due to the low transformation rate of the research results of giant embryo rice and the lack of market application and promotion; secondly, the high price of giant embryo rice can not be ignored as an important factor. However, with the continuous increase of population and market demand and the continuous emergence of intensively processed products, many advantages of giant embryo rice will be further highlighted, and it will have broad application and promotion prospects.

Acknowledgments

This work was financially supported by National Natural Science Foundation of China (U1604110, 31801332, 31600992), Key Project of Science and Technology in Henan Province (192102110119, 182102110442), The Training Plan of Young Backbone Teachers in Colleges and universities of Henan Province (2019GGJS162), Key Scientific Research Projects of Universities in Henan Province (19A180030), Nanhu Scholars Program for Young Scholars of XYNU (2016054), Major Science and Technology Project in Henan Province (121100110200) and Institute for Conservation and Utilization of Agro-bioresources in Dabie Mountains.

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