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The Nutritional Value and Application of Black Rice-A Review

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Abstract

Black rice is the main member of the special rice family, and it is also a rare grain and oil crop resource in China. Black rice has special medicinal components and high nutritional value. In recent years, the research on the nutritional value and application of black rice has become an important direction, and a series of important progress has been made. In this paper, the nutrition and its influencing factors of black rice, the main ways to improve eating quality, the health care and medical functions of black rice were reviewed. Meanwhile, the application prospect of black rice has also been prospected. Therefore, this review will provide an important theoretical basis for genetic improvement and breeding of new varieties of black rice.

Keywords: Black rice; Nutrition; Quality; Healthcare; Medical care.

1. Introduction

Black rice is the main member of special rice family, and it is also a rare grain and oil crop resource in China. Black rice has special medicinal ingredients and high nutritional value, and is known as “blood enriching rice”, “medicinal rice”, “longevity rice” and “immortal rice”. Black rice is not only rich in protein, essential amino acids, vitamins, unsaturated fatty acids, calcium, iron, zinc and other mineral nutrients, but also rich in bioactive substances such as flavonoids, anthocyanins, alkaloids, sterols, etc., but also contains black rice pigment with important medicinal value. Black rice has a variety of biological activities such as antioxidant, resist inflammatory, anti-cancer, prevention of cardiovascular and cerebrovascular diseases [1, 2]. Therefore, it is of great theoretical significance and application value to study the nutrients and quality of black rice for the cultivation of new black rice varieties with good quality in later stage.

The nutritional value of black rice is higher than that of ordinary rice, and the content of trace elements and nutrients is generally higher than that of high-quality rice. The protein content of black rice is about 26.4%. The average protein content of black rice is 11.5 g per 100 g, which is 6.8% higher than that of ordinary rice; Fat 2.7 g, 1.9 times higher than rice [3]. In addition, black rice also contains amino acids needed by human body, and its total amino acid content is 15.9% higher than that of rice. The amino acid content of brown rice is 9.34 $g.mg^{-1}$, black rice is 11.28 $g.mg^{-1}$, and the highest is 15.11 $g.mg^{-1}$. Lysine is 3 ~ 3.5 times higher than rice; The content of arginine was 1.2%, 2.12 times higher than that of rice [4]. The content of plant fat in black rice is about 3.9%, which is 1.9 times higher than that in ordinary white rice. Unsaturated fatty acids, oleic acid and linoleic acid are the main components of plant fat [5]. Therefore, the research on black rice has broad market prospects and important application value.

Black rice is rich in iron, zinc, copper and other trace elements, and the content of Na, Mg, K, CA, Al, V, Mn and Fe in black rice is higher than that in white rice [6]. Among them, the variation range of Fe content was 15 -2.37 $mg{\cdot}kg^{-1}$, Zn was 23.92 -145.78 $mg{\cdot}kg^{-1}$, Mn was 18.33 -161.92 $mg{\cdot}kg^{-1}$, P was 2.89 -4.92 $mg{\cdot}kg^{-1}$, which was not only affected by environment, but also regulated by genetic effects [7, 8]. The genetic effects of Fe, Zn, Mn and P contents in black rice varieties were analyzed by using the genetic model of seed endosperm quantitative traits of cereal crops. The results showed that the contents of four mineral elements were affected by seed direct genetic effect, maternal effect and cytoplasmic effect at the same time. The seed direct effect of Fe, Zn and Mn contents was greater than maternal effect and cytoplasmic effect; P content was mainly affected by direct additive effect of seed, maternal additive effect and dominant effect [9]. The contents of iron, zinc and copper in black rice and black rice pigment can be determined by atomic absorption spectrophotometer after digestion with nitric acid nitric acid mixed acid by conventional method.

Black rice pigment belongs to flavonoid anthocyanins, which belongs to plant polyphenols. Black rice is conjugated with 3 rings of anthocyanins from the multi conjugated aromatic system. It has high biological activity, and has the effect of reducing the incidence rate of heart crown, improving the visual acuity, antioxidation and anticancer activity [5, 10]. There are more than two main components of black rice anthocyanin pigment, one is anthocyanin-3-glucoside, the other is anthocyanin rhamnoside or hygroscopic hypericin, which are easily soluble in ethanol and glycerin, but difficult to dissolve in ether, chloroform and other solvents [11]. The stability of black rice pigment is affected by temperature, pH, nitrogen level, light intensity, chemical reagents and food additives [12, 13]. When studying the stability of anthocyanins from black rice bran, it was found that high temperature would lead to the degradation of anthocyanins [14]. Plant growth at the low level of N, P, K showed a higher pigment content. Nutritional stress is also an environmental factor, which can affect the expression level of anthocyanins. The heredity of anthocyanin expression is complex. The position of anthocyanin expression is controlled by heredity. Light intensity is the key factor. Strong light leads to high level expression. The synthesis of anthocyanin is controlled by the phytochrome system. Therefore, the role of red light in the spectrum is the most effective [15]. The absorbance of black rice pigment decreased due to the strong oxidizing or reducing substances, and the food additives sucrose and glucose had no obvious effect on black rice pigment [16]. Therefore, black rice pigment is not stable under some conditions.

Due to the complexity of black rice pigment composition and properties, various methods are different in material treatment, solvent selection, pigment content expression, etc. [17]. Spectrophotometry, high performance liquid chromatography, solvent extraction, ultrasonic extraction, microwave extraction and enzymatic hydrolysis can be used to extract pigment from black rice [18]. Different extractant, temperature, pH value, extractant concentration and solid-liquid ratio had different content of black rice pigment. Kang et al. Found that 70% acidified ethanol had the highest anthocyanin extraction concentration of 461.72 mg / L when studying the optimization process of anthocyanin extraction from black rice, indicating that the pH of the extraction solution affected the anthocyanin yield [19]. The extraction solvent also has a great influence on the extraction process of black rice anthocyanins.

When water is used as the extraction solvent to study the large-scale extraction process of black rice anthocyanins, the best effect is obtained when the solid-liquid ratio is 1:12, the extraction temperature is 50℃, the extraction time is 80 min, and the pH of the extraction solution is 3.2 [20]. However, in all the methods, 95% ethanol was used as the extraction agent, the solid-liquid ratio was 1:45, and the pH was 3.0. The optimal extraction conditions were 80℃ water bath for 90 minutes [21]. Membrane separation technology and macroporous resin separation and purification technology are the most common in the research of black rice pigment purification technology. Black rice anthocyanins can be purified by membrane separation technology, which has no loss of color value and can also remove salt and lipid [22]. Therefore, these results have important practical significance and potential application value for the extraction of black rice pigment in the future.

2. Nutritional Quality and Taste Quality of Black Rice

2.1. Nutritional Quality and Function of Black Rice

Black rice is a kind of colored rice rich in anthocyanins, flavonoids, phenolic acids and other active substances [23], which has the functions of effectively removing free radicals that damage lipids, protein and DNA, resisting cancer, allergy, obesity and preventing arteriosclerosis and cardiovascular diseases [24]. Black rice is mainly in the form of rice, which has unique appearance and taste, rich nutritional value and biological activity [25]. Thereby having good development prospect and wide application value.

The seed coat of black rice is mainly caused by anthocyanin accumulation, which is mainly concentrated in the seed coat [26]. Anthocyanin is a water-soluble compound formed by two aromatic rings connected by oxygen-containing three-carbon heterocycles. The anthocyanin components in black rice are cyanidin-3-glucoside, peony -3-glucoside, cyanidin-3-diglucoside and petunian-3. Brewing wine made from anthocyanin-rich black rice not only has attractive appearance, but also has many physiological active functions and health care functions, which makes black rice wine gradually become a brewing wine with high added value [27]. Flavonoids in black rice can maintain normal osmotic pressure of blood vessels, reduce fragility of blood vessels, prevent rupture of blood vessels and stop bleeding [28]. Anthocyanins belong to flavonoids and polyphenols, which are chemical components that make flowers, fruits, leaves and stems of plants appear blue, purple and red [29]. In addition to color development, anthocyanins also have a variety of biological activities, which can eliminate free radicals, stabilize singlet oxygen, resist cancer, inflammation, allergy, diabetes, resist cognitive decline, prevent atherosclerosis, cardiovascular diseases, prevent obesity, improve iron deficiency anemia and other physiological functions [30]. Anthocyanins need to be transported to cells when they play a role in vivo, and this process is influenced by protein. In the process of binding anthocyanins and protein in vivo, a certain balance was achieved between free anthocyanins and bound anthocyanins.

After interaction with β-LG, the ability of anthocyanin to scavenge free radicals increased, but the increase degree was lower than the antioxidant activity of β-LG, and there was a certain antioxidant shielding effect between β-LG and BRA [31]. Anthocyanins are extremely unstable and will change with the change of pH. The effect of pH on anthocyanins first increased and then decreased with the increase of pH, which was more stable in acidic environment. With the increase of alkalinity, the content decreased obviously. Anthocyanins are sensitive to temperature changes, and tend to deteriorate when the ambient temperature of anthocyanins is high. The content of anthocyan will decrease with the increase of temperature, and with the increase of time, the anthocyanin will decrease at the same temperature. Temperature has a very important influence on the storage of anthocyanins, so we should keep the low temperature environment as far as possible when storing anthocyanins, so as not to cause the destruction of anthocyanins. Compared with the influence of temperature and pH on the chemical properties of anthocyanins, the influence of oxidant is less. The chemical properties of black rice in oxidant vary greatly. Anthocyanins should be kept in relatively low temperature and relatively acidic environment as far as possible. Oxidants are destructive to anthocyanidins. Generally, reductants have oxidation resistance to protect anthocyanidins from oxidation. However, if high concentration of vitamin C is added to anthocyanidins, the stability of anthocyanidins will be reduced [1]. Because anthocyanins and other flavonoids have remarkable effects in disease resistance and oxidation resistance, and are easily affected by many factors, it is of great significance to continuously optimize the technical means of purifying flavonoids.

Anthocyanins and flavonoids are the important material basis of black rice's antioxidant function. The antioxidant extracts of black rice contain anthocyanins and other flavonoids, which make black rice show antioxidant function. The total phenol of black rice has strong antioxidant activity and can scavenge active oxygen free radicals. Total phenol content is also an important factor affecting the antioxidant capacity of black rice varieties. There is a significant positive correlation between total phenol antioxidant capacity and total phenol content. The total phenol content in different black rice seed coats is related to the color, size and weight of black rice. The difference can reach several times or even dozens of times under the control of genotype, processing conditions and storage conditions, and its composition is also different from each other. The content of trace elements such as potassium, magnesium, calcium, iron, zinc, manganese and phosphorus in black rice is higher than that in white rice. Trace elements have an important influence on the growth and metabolism of microorganisms during brewing. Black rice nutritional fermented wine has unique flavor, and its special aroma components are due to the inclusion of alcohols, acids, esters, phenols, ketones and other substances; Among them, the content of phenylethanol is high, and it has pleasant rose fragrance. At the same time, black rice is rich in amino acids, including 17 kinds of amino acids such as proline, alanine and glutamic acid, and various vitamins. The contents of total flavonoids, total polysaccharides and total anthocyanins were significantly higher than those of white rice [32]. The content of various nutrients in black rice is significantly higher than that in white rice, which has higher nutritional value.

2.2. Taste Quality and Improvement Technology of Black Rice

Black rice skin is hard and contains a lot of cellulose and pectin, which leads to difficult cooking and poor taste quality, which limits the development and utilization of black rice to a great extent [33]. Pre-gelatinizing black rice and processing it into pre-gelatinized black rice is one of the ways to improve the cooking quality and eating quality of black rice. Drying is a very important link in the production process of pregelatinized black rice. The drying characteristics of pregelatinized black rice and the internal moisture change law of black rice directly affect the drying efficiency and product quality of pregelatinized black rice. It contains minerals in a reasonable proportion and all essential amino acids for human body, and has medicinal value and health care functions such as anti-oxidation, anti-inflammation, scavenging free radicals and lowering blood pressure. The viscosity of pregelatinized black rice also decreases with the increase of drying temperature [34]. The decrease of adhesion is related to the leaching of low molecular weight compounds such as amylose and amylopectin, and amylopectin is considered as the main part of starch leached during cooking. When making nutrition porridge with black rice, the addition of black rice has a significant impact on the quality of nutrition porridge. With the increase of black rice, the sensory of nutrition porridge increased first and then decreased. When the addition amount of black rice is 2%, the taste of nutrition porridge is comfortable, the taste is thick and long, and the color is uniform. When the amount of black rice is more than 2%, the sense of nutrition porridge will decrease, because too much black rice will affect the texture of nutrition porridge. Black rice contains more amylopectin, and its color is easy to darken and its taste is rough [35]. Amylose content and amylopectin content in black rice are important factors that affect the taste quality. In production and application, it is necessary to properly adjust the amount of black rice and optimize the processing technology of black rice to achieve the best taste and nutrition.

Starch is the most important nutrient component of black rice and all rice, including linear amylose with low molecular weight and amylopectin with high molecular weight. The amylose content in waxy black rice is less than 2%, which can effectively improve the liquor yield as a raw material for liquor making. Low amylose makes the gelatinized product of black rice have better viscosity. In the brewing process, it is easier to be hydrolyzed by amylase into monosaccharides and dextrins with small molecules. A certain amount of dextrins as taste substances can improve the mellow degree of wine body. It is precisely because of the large amount of cellulose in the epidermis of black rice that it takes a long time to cook and has poor edible quality, which makes it difficult to cook and eat like ordinary rice, and also affects its consumption and value. Enzymatic hydrolysis with cellulase can not only shorten the cooking time, but also improve the edible quality of black rice, which is one of the ways to improve the cooking quality of black rice. Taking the cellulose content of black rice as an index, the suitable enzymatic hydrolysis conditions are as follows: pH5.2, enzymatic hydrolysis temperature 45°C, cellulase dosage 0.09 mg/mL, and enzymatic hydrolysis time 4 h. After enzymatic hydrolysis, the cellulose content in black rice is degraded by 24%, and the cooking time of black rice is shortened by 60% [17]. It can effectively improve the cooking quality of brown rice, shorten the cooking time and improve its utilization value.

3. The Food Health Function of Black Rice

According to the compendium of Materia Medica written by Li Shizhen, a famous doctor in the Ming Dynasty, black rice has the effects of "nourishing yin and kidney, strengthening spleen and liver, brightening eyes and promoting blood circulation". Chinese medicine believes that black rice has the functions of nourishing yin and kidney, strengthening stomach and warming body, improving eyesight and promoting blood circulation, smoothing dampness and benefiting essence, tonifying lung and warming tendons. It can be used as medicine and food. It has excellent effect in treating dizziness, night blindness and tinnitus. It can prolong life if taken for a long time. Modern medical research has confirmed that black rice is indeed an ideal tonic for human body, and has good effect in the treatment of arthritis, rheumatism, anemia and postpartum weakness of women [36]. Functional evaluation studies have proved that black rice has health functions such as scavenging free radicals, biological anti-oxidation, delaying aging, improving iron-deficiency anemia, lowering blood lipids, and inhibiting arteriosclerosis [37]. Therefore, eating more black rice has an important effect on our health.

Before the 1980s, people ate black rice singly, mainly used for cooking porridge for women or patients to nourish their bodies. However, in the past 10 years, the deep processing industry of black rice in my country has developed rapidly. Today, there are more than 100 kinds of foods developed with black rice as raw materials [38]. Including the application of fermentation technology to brew wine and beverages, the application of extrusion technology to process paste and pastry foods, the application of biochemical technology to refine medicine and health products, and the application of other processing technologies to produce black rice food. The research and development of black rice series food shows that people are gradually exploring and discovering more effects of black rice. Studies have shown that nutritional powder made with black rice as the main raw material can not only promote the growth of young rats, but also increase the content of four trace elements Ca, Fe, Mg and Zn in the serum [39], and increase hemoglobin and red blood cells in the blood of mice. The content can also increase the lymphocyte transformation rate, peritoneal macrophage phagocytic rate and phagocytic index of mice, but it has no obvious effect on white blood cells. Black rice can scavenge free radicals and is a natural antioxidant. Free radical is the product of metabolism in the body. It is the intermediate product of biochemical reaction in the process of life activities. Black rice pigment solution has a certain reduction ability, and the reduction ability increases with the increase of its concentration. At the same time, black rice pigment also has a strong scavenging effect on hydroxyl radical and DPPH [34, 40]. In recent years, studies have found that black rice anthocyanins have strong free radical scavenging and antioxidant activities, and are an important source of natural antioxidants. Many diseases are related to excess free radicals, and the hydroxyl structure of anthocyanins makes them have strong ability to capture and

scavenge reactive oxygen species. Therefore, by scavenging free radicals, it can play a protective role in the damage of biological macromolecules induced by free radicals, maintain the fluidity of cell membrane and the conformation of protein [10]. The Fenton reaction was used to study the inhibition of black rice anthocyanin capsule and black rice pigment on hydroxyl free radical and superoxide anion and their total antioxidant activity. It was also found that black rice anthocyanin capsule and black rice pigment could effectively scavenge free radical and had good antioxidant effect [41]. Therefore, black rice has the function of scavenging free radicals and biological antioxidation.

Black rice can reduce blood lipid. Hyperlipidemia is a common disorder of lipoprotein metabolism, which is one of the main risk factors of cardiovascular and cerebrovascular diseases, and seriously threatens human health [42]. Dietary black rice and black rice bran can not only reduce the blood lipid level of experimental animals, inhibit the occurrence and development of atherosclerosis (AS), but also reduce the level of oxidative stress and improve the activity of antioxidant enzymes. It is speculated that this effect is related to anthocyanins [43, 44]. The effects of black rice pericarp anthocyanin (Black rice pericarp anthocyanin, BRPA) on blood lipid level, antioxidant enzyme activity and lipid peroxidation product malondialdehyde (Multiple Displacement Amplification, MDA)content in experimental hyperlipidemia rats were observed: After ingestion of BRPA, the blood lipid level and atherosclerotic index (AI) of hyperlipidemia rats were significantly lower than those of the control group, while the activities of TAC, SOD and GSH-PX in serum and liver were significantly increased, the titer of serum OX-LDL antibody was significantly decreased, and the production of MDA was significantly reduced [45]. Therefore, BRPA has lipid-lowering and antioxidant activities, and can reduce the risk of atherosclerosis. The regulation of black rice on blood lipid in female mice shows that black rice can reduce the cholesterol level of the body, and its cholesterol lowering mechanism may be realized by regulating the expression of cholesterol metabolism related genes in the liver [46]. Therefore, black rice can reduce the level of blood lipids and ensure human health.

With the increase of age, many middle-aged and elderly people do not pay attention to diet control at ordinary times, and often eat some foods with high fat content, which causes dyslipidemia and arteriosclerosis. By studying the effect of black rice anthocyanin extract on advanced atherosclerotic plaque in ApoE deficient mice, it was found that black rice anthocyanin extract could significantly reduce the levels of total cholesterol (TC), total triglyceride (TG) and low density lipoprotein cholesterol (LDL-C) in Hongqing mice, and reduce the plaque area of innominate artery, Reduce the content of matrix metalloproteinase-1 (MMP-1) in plaque [47]. It has also been proved that dietary black rice bran can inhibit the formation of atherosclerotic plaque in ApoE gene deficient mice [48]. Therefore, we can eat more black rice to prevent arteriosclerosis. At the same time, we can mix various nutrients reasonably with food, adjust recipes according to the season, and eat more black rice to form a healthy body.

4. Medical Therapeutic Effect of Black Rice

Black rice is a kind of black rice. It is a kind of rice for both medicine and food, belonging to the category of glutinous rice. Black rice is a kind of characteristic variety formed by long-term cultivation of gramineous rice. Black rice, also known as black japonica rice, has dark skin and fine texture, which is slightly flat than ordinary rice [49]. Black rice is rich in nutrition, containing a variety of trace elements [50] and vitamins [51]. Black rice is also a kind of multifunctional rice, which not only gives people excellent taste in food, but also has great significance in the field of research and development and medical treatment. This paper discusses the medical treatment related functions of black rice, which provides important guidance and reference value for the further development and application of black rice resources and industrial production.

Modern medicine has proved that black rice is rich in protein, vitamins, natural melanin, iron, zinc, calcium and other trace elements necessary for human body, amino acids and other substances that play an important role in human body. Black rice also has the effects of nourishing yin and kidney, invigorating spleen and liver, tonifying spleen and stomach, invigorating qi and blood, nourishing liver and eyesight. Modern medical research also shows that regular consumption of black rice is conducive to the prevention and treatment of dizziness, dizziness, anemia, white hair, eye diseases, waist and knee soreness, lung dry cough, constipation, adverse urination, kidney deficiency and edema, loss of appetite, spleen and stomach weakness, etc. Black rice with other substances can also treat the corresponding diseases, for example, black rice and glutinous rice cooked together, can clear heat and moisten lung, If you add Gastrodia and tremella, it has the effect of invigorating spleen and kidney; If it is boiled with longan meat, tremella, jujube, Coix, lily, sesame and rock sugar, it is the palace tonic "Bazhen Decoction", which has an excellent therapeutic effect on dizziness, anemia, white hair and eye diseases. Black rice wine made of black rice can also promote sleep and assist in the treatment of rheumatoid arthritis. In medicine, black rice mainly has anti-aging [52], reducing blood glucose [53], regulating blood lipid [54], and can participate in the regulation of various related diseases. Therefore, the in-depth study of black rice in medicine has important scientific significance and potential market application value.

4.1. Black Rice Can Resist Aging

Research shows that the darker the color of rice, the higher the nutritional value. What is black rice? Rice can be divided into many kinds according to taste and color. According to the taste, there are glutinous rice, japonica rice and indica rice, According to the color, there are white, yellow, green, red, purple, brown, black and other colors of rice. Whether it is glutinous rice, japonica rice or indica rice, there are purple, brown or even basically black varieties. People often call them black rice. The general law of food nutritional value tells us that the darker the color of the same food raw material, the higher the nutritional value. Rice also conforms to this law. Therefore, the

nutritional value of black rice is much higher than that of refined white rice. Melanin has anti-aging effect. The reason why the color of black rice is different from other rice is that the outer cortex contains anthocyanin pigments, which have strong anti-aging effect. Studies at home and abroad show that the darker the color of rice, the stronger the anti-aging effect of epidermal pigment. The effect of black rice pigment is the strongest among all kinds of color rice. Therefore, black rice can resist aging. The color of black rice is different from other rice, mainly because it contains anthocyanins in the outer cortex, which has a strong anti-aging effect. In the research of black rice anthocyanin in delaying the aging of fruit flies, the quantitative black rice anthocyanin feeding of fruit flies can extend the life span of fruit flies and delay the senescence of fruit flies [55]. The results of genome sequencing show that the homology of human gene and Drosophila is as high as 80%, which provides a strong theoretical basis for further research on the mechanism and pathology of human aging resistance.

4.2. Black Rice Can Reduce Blood Sugar

The fluctuation of blood sugar will lead to the occurrence of corresponding diseases, and excessive blood glucose will lead to the occurrence of diabetes. Diabetes is a major disease threatening the health of our people. Choosing low glycemic index foods will help prevent and control the occurrence and development of diabetes to some extent. Therefore, maintaining the stability of blood sugar and avoiding greater fluctuation is the key link in the treatment of diabetes. The main choice of diabetes diet therapy is to choose a reasonable staple food with low blood sugar (mainly carbohydrate food)

Black rice contains more dietary fiber, starch digestion speed is relatively slow, blood glucose index is only 55 (rice is 87), therefore, eating black rice will not cause blood glucose fluctuations as eating ordinary rice. Through the study on the hypoglycemic effect of several procyanidins and the combination with common food ingredients, the results showed that black rice is the raw material for developing low glycemic index foods and can be used in the adjuvant treatment of diabetes mellitus [56]. This proves from the side that black rice can reduce blood sugar. It provides an important basis for further research on the assistant treatment of black rice for diabetes and its effect on blood sugar.

4.3. Black Rice Can Regulate Blood Lipid

Blood lipid is the general term of neutral fat (triglyceride and cholesterol) lipids (phospholipids, glycolipids, sterols and steroids) in plasma, which widely exists in human body and is essential for basic metabolism of living cells. Too high or too low blood fat is bad for the body. No stable blood lipids in the proper range can lead to obesity, arteriosclerosis, hyperlipidemia, coronary heart disease, diabetes, nephrotic syndrome and other cardiovascular diseases. Therefore, it is important to study the black rice which can control blood lipid. In the study on the optimization of microwave-assisted extraction process of anthocyanins from black rice and its hypolipidemic function, mice were used to do experiments, and it was found that anthocyanins from black rice could reduce the increase of LDL level caused by high-fat diet and improve the lipid level of hyperlipidemic mice [29]. In the regulation of blood lipid by black rice, in addition to the anthocyanins of black rice, the black rice skin of black rice also plays an important role. Studies have shown that different doses of black rice skin extract can reduce the blood lipid level of rats with hyperlipidemia [45]. Black rice not only plays an important role in regulating blood lipids, but also can affect and regulate the level of blood lipids in combination with other food substances under certain conditions. In the study on the lipid-lowering effect and component analysis of black bean and black rice Poria formula, it is known that black bean and black rice Poria formula has a clear lipid-lowering effect on hyperlipidemia patients and experimental hypercholesterolemia mice [57]. Therefore, the above research results provide important theoretical guidance for further exploring the mechanism of black rice and black rice mixed with other active ingredients on regulating blood lipid, and provide strong theoretical guidance for further reducing the damage of blood lipid to human beings.

4.4. Other Functions of Black Rice

There are many important functions of black rice, here is a brief introduction of several black rice involved in disease treatment. Diabetic retinopathy is the most common microvascular complication of diabetes, which seriously threatens patients' vision. Black rice anthocyanins are extracted from the bran of black rice, which is a traditional Chinese food. They have antioxidant, anti-inflammatory and anti-cancer effects. They can protect the retina from photochemical damage. In the study of the protective effect of black rice anthocyanin on diabetic retinopathy, it is found that black rice anthocyanin has strong antioxidant activity. It can protect the retinal damage by improving SOD activity and MDA content. Qi, *et al.* [58] Many genes that cause human diseases can also be found in rats. By studying the rats, we know that black rice anthocyanins play a protective role in diabetic retinopathy, which provides a theoretical guidance for further research and treatment of diseases. Asthma is an inflammatory disease characterized by infiltration of airway inflammatory cells, especially eosinophils, epithelial damage, airway hyperresponsiveness and airway obstruction. Black rice anthocyanins are glycosides formed by the combination of anthocyanins and various sugars. They exist in the cell fluid of fruit, stem and leaf organs of black rice, and have strong antioxidant, anti-inflammatory and anti-tumor effects. In the study of anti-inflammatory effect of black rice anthocyanin on asthma, it was found that black rice anthocyanin could significantly inhibit the infiltration of airway and lung inflammatory cells in asthmatic mice [59]. Allergic asthma is a complex inflammatory airway disease, the most common symptoms are airway inflammation, mucus secretion, airway hyperresponsiveness. In recent years, studies have found that black rice anthocyanins can inhibit the activation of mast cells and play an anti allergic role, inhibit the secretion of tumor necrosis factor and IL-6 induced by lipopolysaccharide, and also play an important role

in anti-inflammatory. The asthmatic model of mice was induced by chicken egg albumin. The effect of black rice anthocyanin on inflammation in asthmatic mice was observed, and the anti asthmatic effect of black rice anthocyanin and its possible mechanism were determined [60]. This provides an important reference and theoretical significance for further study of the effect of black rice anthocyanins on airway inflammation in asthmatic mice. Because many genes leading to human diseases can also be found in mice, through the study of mice, we know that black rice anthocyanins play a certain role in inhibiting asthma inflammation, which provides a favorable theoretical guidance for further research and treatment of diseases, and also provides a certain theoretical basis for further study of its mechanism.

All kinds of tumors and cancer diseases have always been a problem that people are worried about and want to overcome and solve. In recent years, the anti-cancer and anti-tumor effects of black rice anthocyanins have attracted more and more attention. Black rice anthocyanins can inhibit the growth and proliferation of breast cancer cells, and promote the apoptosis of cancer cells. The mechanism may be that anthocyanins compete with ATP to bind to the HER-2 receptor, regulate its phosphorylation level, and reduce the activity of metastases. , Weaken the ability of breast cancer cells to metastasize [61].Therefore, the above results provide a favorable theoretical guidance for further study of the important role of black rice and the mechanism of treatment of related diseases.

5. Prospect of Black Rice Research

Although there are some researches on the nutritional components, nutritional quality, cooking and eating quality, processing quality, appearance quality, medical treatment and food health care of black rice, there are still some problems in the research of black rice, especially the anthocyanins which play a major role in the nutritional quality of black rice. For example: (1) the traditional black rice anthocyanins extraction, separation, purification time is long, high cost, low yield, high cost of wastewater treatment. (2) Due to the difficulty in purification and preparation of black rice anthocyanin standard, high cost, expensive standard and high equipment requirements, it is difficult to obtain a single component of anthocyanin. (3) Black rice anthocyanins have the effects of antioxidation, liver protection, anti lipid, anti-tumor, immune regulation, weight loss and so on. However, there are many studies on the physiological effects of black rice in vitro environment simulation, and relatively few studies on animal experiments and clinical application, especially in the structure-activity relationship, dose-effect relationship and molecular and physiological mechanism of black rice anthocyanins. (4) The content of anthocyanin in black rice is relatively low. How to use bioengineering technology and agricultural technology to screen high content black rice varieties and improve the content of anthocyanin in black rice still need further research [62]. These tasks are difficult problems and also face great challenges. Therefore, in-depth research on the nutritional components, nutritional quality, cooking and eating quality, processing quality, appearance quality, medical treatment and food health care of black rice has broad application prospects, especially the research on cooking and eating quality and medical treatment. Through reasonable consumption of black rice, many diseases related to human beings can be treated, but many of the influencing factors and the mechanism of disease treatment are still not very clear. Therefore, it is still an important development direction in the future to conduct in-depth research and crack the mechanism of affecting and treating the corresponding diseases, and to develop and utilize the potential value of black rice.

There are many health products related to black rice in the market, such as black rice wine, black rice vinegar, black rice health tea, black rice noodles, etc. However, black rice anthocyanin products are still rare in the domestic market. At present, black rice anthocyanin capsules are used. A batch of anthocyanin products represented by the company are under development and trial production. With the development and sales of black rice and its anthocyanin health food, the market prospect of black rice anthocyanin will be very broad. Further in-depth research on the industrialized automatic preparation technology, separation and purification technology of black rice anthocyanin, the relationship between the structure of black rice anthocyanin and biological activity, the clinical trial research of black rice anthocyanin pharmacology and the development and production of related products are still important in the future Direction of development.The current market consists of black rice and other nutrients such as soybeans, black beans, tuckahoe and other different foods when properly matched, which can not only maintain health, but also treat related diseases. For example, black rice and glutinous rice can be boiled at the same time to clear heat and nourish the lungs; if it is added with gastrodia elata and white fungus, it can invigorate the spleen and kidney; if it is cooked with longan meat, white fungus, red dates, barley, lily, sesame, and rock sugar, it is a royal tonic "Bazhen Decoction" has an excellent therapeutic effect on dizziness, anemia, gray hair and eye diseases. Therefore, with an in-depth understanding of the main nutritional components and functions of black rice, the development and production of different formulas and related products is also an important direction for the development of black rice in the future.

In conclusion, the industrial automatic preparation technology, separation and purification technology, and the relationship between the structure and biological activity of black rice anthocyanins were further studied, Black rice anthocyanin pharmacological clinical trial research and related product development and production, In depth study and analysis of the impact and treatment mechanism of corresponding diseases, the reasonable combination of black rice and other nutrients and the test of different formulas and related products In-depth research on product development and production has great prospects for the further development and application of black rice resources and industrial production, and will be an important direction for the development of black rice in the future.

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