Advances in Researches of Functional Rice

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Abstract Functional rice has functions of adjusting human physiological functions of and preventing diseases. At present, there are researches both at home and abroad about the relationship between nutritional quality and physiological active substances of rice and human physiological activities. Through conventional breeding, gene mutation technology, and molecular-assisted selection (MAS) technology, it is feasible to select and breed new rice varieties and plants with certain health care functions.

Key words Rice, Health care functions, Current situations of researches, Development direction

1 Introduction

Functional rice contains certain physiological active substances which can adjust human physiological functions[1]. Its appearance, taste, and nutritional components are similar to ordinary rice varieties. The differences lie in that functional rice contains certain physiological active substances, so it can adjust human physiological functions, strengthen physiological prevention mechanism, raise physical strength and vigor, and prevent special diseases and delay senility[2]. Development of functional rice benefits from functional foods. Studies of functional foods started from the 1970s in Japan, European and American countries. With social and economic development, material supply becomes abundant, people's living conditions get improved, then people's diet structure and habit change accordingly. At the same time, series of sub-health problems occur due to imbalance in intake of nutrients, and related research institutions and scholars begin to pay attention to the relationship between diseases and nutrients of staple foods[3]. Researches indicate that patients with kidney disease and diabetes may be poisoned if eating rice containing glutelin higher than 4%[4]; patients with hypoferric anemia can effectively alleviate the symptom through eating rice with high content of organic iron[5]; patients with high blood pressure can reduce blood pressure through eating rice with high content of GABA (Gamma-Aminobutyric Acid)[6]; children lacking Zn may have anorexia, slow growth and development, and mental retardation[7]. On this basis, related research institutions have developed and produced functional foods with clear functions oriented towards certain people, such as foods for strengthening physical conditions (improving immunity and activating lymphatic system), foods for preventing diseases (such as high blood pressure, diabetes, coronary heart disease, constipation, and tumor, *etc*), foods for physical recovery (controlling cholesterol, preventing blood platelet agglutination, and adjusting hemopoietic function), and foods for adjusting biological rhythms (nerve center, peripheral nerve, intake and absorption functions), and foods for delaying senility[8]. In recent years, many varieties of functional rice have been developed at home and abroad.

According to physiological functions, functional rice can be divided into rice for strengthening physical conditions (such as high protein rice and functional peptide rice), disease-preventing rice (such as Se-enriched rice, Zn-enriched rice, and high Vitamin A rice), rice for health recovery (such as low-sugar functional rice and kidney tonifying rice), rice for adjusting biological rhythms (such as low glutelin rice and low allergenic rice), and rice for delaying senility (such as black rice and red rice).

2 Overview of foreign researches about functional rice

Japan, European and American developed countries attach great importance to researches about essential nutrients and physiological active components of rice. In 1994, scholars of International Rice Research Institute (IRRI) studied genetic breeding of Fe-enriched and Zn-enriched rice in view of nutritional deficiency of Southeast Asian people[9]. Since the 1980s, Japan has started studies on functional rice; from the 1990s, Japan developed a series of new varieties of functional rice[10]. Nutritional researches show that rice protein consists of albumin, globulin, alcohol soluble protein, and glutelin, and glutelin (accounting for about 70% of total protein) is main component of protein that can be absorbed by people. However, patients with kidney disease and diabetes will aggravate the symptom if eating foods containing too high protein. Therefore, low glutelin rice is suitable for patients with kidney disease and diabetes. National Institute of Agrobiological Sciences (NIAS), the largest agricultural fundamental scientific research institution in Japan, developed rice variety NM67 with low soluble protein and stable properties through taking high quality rice Nihomasari as material, treatment with chemical mutagen ethylene imine, with the aid of molecular-assisted selection technology[11]. Genetic analysis indicates that low glutelin properties of NM67 are controlled by individual dominant gene. Taking NM67

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mutant as parent rice, NIAS developed LGC-1 (low glutelin content-1) with glutelin content lower than 4%. Clinical application indicates that rice with low water soluble protein is effective assisted food for patients with kidney disease and diabetes.

With cooperation of NIAS, using chemical mutation method, the School of Agriculture of Kyushu University developed giant embryo new rice variety Haminuori (with aminobutyric acid content 4 times higher than ordinary rice varieties) and low allergenic rice variety[12]. After cooking, GABA content of giant embryo rice will significantly increase. GABA has functions of soothing the nerve and reducing blood pressure and blood ammonia. Patients with high blood pressure can reduce blood pressure, improve lipid metabolism, and prevent arteriosclerosis through eating rice with high content of GABA. Low allergenic rice can be specially taken by people allergenic to rice because low allergenic rice contains higher allergenic protein (16KD allergenic protein) than ordinary rice varieties. Through agrobacterium mediation, the School of Agriculture of Kyushu University imported iron gene of soybean to Koshihikari rice, and developed new Fe-enriched rice variety, the Fe content of rice is up to 40 – 45 mg in one kilogram rice, 2 times higher than ordinary rice varieties, thus it is suitable for patients with hypoferric anemia. In 2000, Fe-enriched rice variety IRl64 was approved by agricultural resources and assets review meeting organized by Ministry of Agriculture, Forestry and Fisheries of Japan[13]. Using transgene technology, Hokko Chemical Industry, Co., Ltd developed new rice variety with content of tryptophan and lysine 90 times and 10 times higher than ordinary rice varieties[14]. Tryptophan and lysine can not be synthesized within human body and must be absorbed from food.

In the 1990s, trans-national agricultural biological companies Monsanto and Syngenta started to care about functional rice, and used their abundant financial support to carry out researches of functional rice breeding. With the aid of agrobacterium mediation, Swiss Federal Institute of Technology in Zurich introduced two types of plant genes (nicotine amine synthetase and ferrate protein synthetase) into rice seeds, developed super Fe-enriched GM rice with Fe content about 6 times higher than ordinary rice varieties[15]. Syngeta imported gene of β-caritinoid (forebody of Vitamin A) into rice genes and developed new GM rice with Vitamin A content about 20 times higher than ordinary rice varieties[16].

3 Overview of domestic researches about functional rice

For a long time, there is the theory of "medicine and food being the same origin and having the same use". In Compendium of Materia Medica written by Li Shizhen, there are following records: black rice cures acute throat impediment, adjusts medial Qi, cures rheumatic arthritis, paralysis, and born white hair; rice-grain sprout can treat anorexia and disordered digestion; in Dietetic Materia Medica written by famous Chinese Materia Medica expert in Tang Dynasty, Meng Shen, there are following records: brown rice has functions of arresting diarrhea and treating dysentery, reinforcing middle-warmer and replenishing Qi, strengthening sinews and bones, and warming veins; red rice is sweet in taste, warm in nature, and rich in iron, has functions of replenishing blood, preventing anemia, clearing free radicals, improving anti-oxidant ability, and delaying the aging process[17]. At present, some domestic research institutions studied nutrition quality and physiological active substances of rice and developed various functional rice varieties. The Development Center of Plant Germplasm Resources of Shanghai Normal University hybridized Japanese rice variety Chunyang and Shanghai rice variety Xiushui 128, and successfully bred high quality kidney-tonifying rice No. 1 which can assist in curing kidney disease[18]. According to analysis of Quality Supervision and Testing Center of the Ministry of Agriculture, the total glutelin content of this new rice variety is 61% lower than Shanghai ordinary rice varieties, so it can be used for assisting in curing kidney disease. The Functional Rice Research Center of China National Rice Research Institute CAAS introduced from Japan special rice varieties and breeding materials special for patients with renal dysfunction or high blood pressure. By means of making assisted selection of backcross populations using SSR marker closely linked with low glutelin traits, and ethyl methane sulfonate (EMS) treatment, it modified main rice varieties of China, and cultivated new rice variety W3660 (Kangdun No. 1, the variety right No.: CNA20020113. 1) suitable for patients with kidney dysfunction and diabetes[19]. The glutelin and phosphorus content of this rice variety are only 60% and 50% of that of ordinary rice varieties. When the heat supply is guaranteed, it can effectively reduce absorption of protein and phosphorus. Patients with kidney disease and diabetes can reduce their kidney burden. Thus, it is very suitable for people with special requirements for protein intake, such as patients with kidney disease and diabetes. In cooperation with Guangzhou Medical University, using space mutation technology, the Rice Research Institute of Guangdong Academy of Agricultural Sciences cultivated aerospace Se-enriched rice having function of curing recurrent oral ulcer (ROU)[20].

Besides, domestic research institutes also carried out selection and breeding studies on rice varieties containing high GABA, Fe, Zn, and special starch. Tropical Crops Genetic Resources Institute (TCGRI) of Chinese Academy of Tropical Agricultural Sciences (CATAS) selected 3 rice varieties suitable for planting in Hainan Se-enriched soil from 1000 rice varieties, the organic Se content of brown rice is up to 300 mg/kg[21]. The Crop Genetic Breeding Research Laboratory in College of Agriculture of Hunan Agricultural University developed late-season indica rice 3029 with Fe content as high as 47. 6 mg/kg[22]. The Biological Research Institute of Guangdong Academy of Agricultural Sciences, using isolated hybrid of rice head, parthenogenesis induction and ovary culture methods, cultivated rice variety Heiyounian No. 3 with Fe content up to 52. 20 mg/kg[23]. Through introduction and domestication, the School of Agriculture and Biology of Shanghai Jiaotong University successfully cultivated new black rice variety Wugong No. 1, the Fe content of this brown rice is up to 62. 77 mg/kg[24].

Zhejiang University and Yunnan Academy of Agricultural Sciences jointly cultivated Functional Rice No. 1, No. 2, No. 3 and Yunzijing No. 82. Functional Rice No. 3 contains high resistant starch, so it is hungry resistant, and it also can delay release and absorption of glucose, has functions of controlling blood sugar, preventing diabetes, keeping fit, preventing and curing constipation and intestine diseases, it is expected to be widely extended in Ailao Mountain area of Yunnan[25]. In cooperation with Ningbo Hemudu Rice Crop Biological Technology Co., Ltd, the Institute of Nuclear-Agricultural Science of Zhejiang University took temperature sensitive high quality early-mature japonica rice as material, adopted aerospace mutation and Co60 gamma radiation to select small grain mutant, and cultivated mini Zn-enriched rice - Lilizi, with Zn content up to 34.1 mg/kg, 3 times more than local ordinary rice varieties[26].

On the whole, domestic researches about functional rice focus on analysis of nutrition quality of rice, but few researches touch upon physiological active substances with health care functions, especially few about clinical functions of physiological active substances[27]. Therefore, it is recommended to make overall planning, combine researches about health care functions of functional rice varieties and modern nutritional medicine, and screen out different functional rice varieties using rich rice resources. At the same time of breeding varieties (strains) and increasing economic value of rice, it can satisfy health care demands of different people. Through food therapy and food replenishment, it is feasible to strengthen physiological prevention mechanism, raise physical power and effort, prevent special diseases, and improve health conditions, so as to promote common development of functional rice researches and modern nutritional medicine.

4 Development direction of researches of functional rice

Rice is the staple grain crop of the world and about 1/3 of the world population takes rice as staple food. China is the source area of rice. The planting area of rice is wide, and about 50% of Chinese population takes rice as staple food. In staple grain for strengthening physical condition, regulating physiological functions, and preventing diseases, biological fortification measure through rice and rice products is one of the most important approaches[28]. Nutrition and agricultural breeding scholars hold that an effective approach for increasing content of physiological active substances is to explore germplasm containing certain physiological active substances, and increase content of physiological active substances using breeding method[29]. At present, both foreign and domestic researches about new functional rice varieties (strains) remain starting stage, so there are still many problems and difficulties in developing functional rice varieties containing certain physiological active substances. To increase physiological active substances of rice, the major method is introduction of exotic genes to rice seeds. The biological security generated from Genetically Modified Organism (GMO) technology is to be further studied, consumers still doubt about GM rice and GM rice products[30].

It is recommended to cultivate high quality, high yield and multi-resistant health-care functional rice varieties (strains) suitable for planting in China through taking full advantage of certain physiological active substances, trace elements and excellent genes, traditional breeding method, combined with modern gene mutation technology and molecular biological technologies (such as molecular assisted selection technology), electrophoretic analysis, amino acid analysis, and atomic absorption analysis[31]. This is a high efficient, safe and popular approach for obtaining functional health-care rice. In addition, with development and constant exploration of biological technologies, the processing technology of physiological active substances of rice is constantly improved. It is recommended to make further clinical researches about physiological functions of certain physiological active substances. Functional rice and its products will be widely developed and applied.

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duce lasting and stable fertilizer effect, with the advantages that chemical fertilizers can not replace, thereby significantly improving radish yield and radish quality. Applying functional organic fertilizer and trace elements could help to significantly improve radish fleshy root yield, increase soluble sugar and vitamin C content, and reduce the content crude fiber, nitrate and chlorpyrifos in organophosphorus pesticides, but there was no significant effect on the content of glucosinolates in radish. Due to the promotion and restriction, growth and decline mechanism, different functional organic fertilizers and trace elements affected radish yield and quality by a series of physiological and metabolic activities, so there was a need to conduct systematic research on the numerical relationship and regulatory mechanism between them, so as to provide technical support for high yield, high quality and high efficiency of radish.

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