Mini Review

Rice Flour: A Promising Food Material for Nutrition and Global Health

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Summary Hunger and malnutrition, especially children, are still global issues today. Rice is a staple food for more than half of the world population and important nutritional source of not only carbohydrate but also protein. In recent aging societies, protein-energy malnutrition in elderly people emerges also as a social issue. Malnutrition in elderly people raises the risk of falling into age-related chronic diseases. Nutritional care can prevent elderly people from such age-related diseases. Rice and rice flour would be good foodstuff for preparation of diet suitable for and preferred by elderly people. Protein content of rice grains, like the other cereal grains, is less than 10% by weight, which is a little lower than meat and cheese, but higher than dairy milk and yoghurt. Nutritional quality of rice proteins is higher than the other cereal grains. Such relatively higher nutritional quality of rice proteins could be due to high copies of glutelin genes evolved from an ancestral gene common to soybean glycinin and resultant high content of legume-type seed storage proteins. Recently, rice flour became to be utilized for various processed food. The rice seed proteins as well as starch are accumulated in specific organelles termed protein bodies and amyloplast in the cells of endosperm and aleurone layer. By milling rice grains to flour particles consisting of protein and starch nanoparticles, processing characteristics of rice starch and proteins could be changed. To develop rice-based processed food for prevention of malnutrition, rice flour particles from various different rice sources could be blended for desired nutritional composition without spoiling the value of product food.

Key Words rice flour, protein body, 11S globulin, protein nutrition, starch granule

1. Rice for Global Health

No less than about 10% of population, about 800 million people, is still malnourished globally in the world. Hunger and malnutrition, especially children, are still global issues as specified by the United Nations in the action agenda, Sustainable Development Goal 2 (1). About 150 million children under 5 y of age were estimated to be too short for their age due to chronic malnutrition. According to USDA statistical data, about 500 million tons as paddy rice were produced per year in 2014–2015 in the world. Rice is a staple food for more than half of the world population. Especially, in rice-producing countries and area in the world such as Southeast Asia and West Africa, rice grains are important nutritional source of not only carbohydrate (energy) but also protein. In addition to the macronutrient, moreover, rice is rich in both micronutrients including vitamins and minerals and health-beneficial phytochemicals such as polyphenols and phytosterols. Thus, rice has globally been one of the most important and valuable food and continues to be into the future.

In several developed countries including Japan, we encounter various problems arising from aging of population and resultant super aging societies. Such aging of society will become a global reality sooner or later in the world. In such aging societies, another

malnutrition emerges as a social issue to be solved. That is protein-energy malnutrition in elderly people. The prevalence of malnutrition in Europe and North America was reported to be relatively low in non-institutionalized older adults (1–15%), whereas it is much higher for older adults in geriatric care facilities (25–60%) and in hospitals (35–65%) (2, 3). Various risk factors might be involved in higher prevalence of malnutrition in elderly people. A recent systematic review showed that significant risk factors unrelated to definite diseases are frailty in institutionalized persons, excessive polypharmacy, general health decline including physical function, constipation, poor or moderate self-reported health status, eating dependencies (loss of independent eating capacity), loss of interest in life and poor appetite (4). Many of these risk factors could be reduced by providing proper diet with both high nutritional quality and good taste and flavor improving appetite, leading to change for the better of malnutrition in elderly people. From this perspective, rice and rice flour would be good food and foodstuff for preparation of diet suitable for and preferred by elderly people.

Obviously nutritional status greatly influences many chronic diseases even more for elderly people (5). Malnutrition induces the decrease in bone mass and muscle bulk, which respectively result in osteoporosis and sarcopenia, and the decline of general physical function leading to locomotive syndrome. It also causes immune

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Fig. 1. Ingredient composition of polished rice and rice bran.

dysfunction resulting in the decrease in resistance to infectious diseases and decline of cognitive ability leading to dementia. Thus, it is clear that malnutrition in elderly people makes them unhealthy and raises the risk of falling into age-related chronic diseases. However, it is also obvious that nutritional care can prevent elderly people from such age-related chronic diseases. If successful, dietary intervention for people with age-related chronic diseases could even restore them to a healthy state. Rice and rice flour could be one of good foodstuffs to be used for dietary intervention because of its superior nutrition and functionality.

2. Rice for Protein Nutrition

Edible part of rice grains, brown rice, contains a diversity of components including macro- and micronutrients and functional phytochemicals (Fig. 1). Protein content of rice grains, like the other cereal grains, is less than 10% by weight, which is a little lower than meat (about 15–25%) and cheese (about 20%), but higher than dairy milk (about 3.3%) and yoghurt (about 4.3%). Although major component of polished rice and rice bran is carbohydrate, mostly starch, about 6–7% of polished rice and even more of rice bran is protein.

Nutritional quality of polished rice is of course lower than animal-source proteins but higher than the other cereal grains. Amino acid score, the balance of essential amino acids, for example, of polished rice is about 65%, which is much higher than that of wheat (35–45%) and maize (about 15%). Moreover, the amino acid score of rice bran is much higher (about 95%) and almost comparable to those of dairy milk, egg and soybean (about 100%). Thus, as is well known, nutritional quality of rice is obviously higher than the other cereals such as wheat and maize, even though they belong to the same plant family, *Poaceae*. A fundamental question is why nutritional quality of rice protein is relatively high.

Major components of plant seed proteins are seed storage proteins, which will be used as a nitrogen source for embryonic development during germination. Several different types of proteins are accumulated as storage proteins, and major ones among them differ among plant species (6). As an example, seed proteins of rice, wheat, buckwheat and soybean as analyzed by Sodium dodecylsulfate polyacrylamide gel electrophoresis (SDS-PAGE) are shown in Fig. 2. The band pattern of protein components of rice is clearly different from that of wheat

Fig. 2. Rice glutelin is a major component of rice seed proteins and resembles soybean glycinin. Total seed proteins for rice, wheat, buckwheat and soybean are analyzed using SDS-PAGE with Coomassie Brilliant Blue staining. Identification of rice and soybean 11S globulins are based on previously reported proteomic studies of rice and soybean seed proteins.

despite that the genus *Oryza* (rice) and *Triticum* (wheat) are monocot plants belonging to the same plant family, *Poaceae*. The rice protein pattern resembles that of soybean proteins rather than wheat one. The two major bands of rice and soybean proteins are acidic and basic subunits of the major storage proteins termed glutelin and glycinin, respectively. The amino acid sequences of rice glutelin and soybean glycinin are significantly homologous (more than 30% overall identity) and the two genes encoding rice glutelin and soybean glycinin are believed to arise by divergence evolution from a common ancestral gene (7, 8). Indeed, a phylogenetic analysis of a rice glutelin gene, *GLUTELIN B1*, and a soybean glycinin gene, *GY1*, shows significant similarity between two genes of monocot and dicot crops (Fig. 3). In this phylogenetic tree, many genes homologous to *GLUTELIN B1* gene (homologues) are present in various species in genus *Oryza*, while two genes, *legmin 1* and *SORB1* respectively from maize (*Zea mays*) and sorghum (*Sorghum bicolor*), are included as well.

Soybean glycinin, presumably the other seed storage proteins similar to this protein as well, forms a large protein hexamer complex with molecular mass over 300 kDa, each subunit of which consist of acidic and basic subunits (9). According to its sedimentation coefficient, soybean glycinin and the other similar seed-storage proteins including rice glutelin are called 11S globulins. The genes encoding these proteins constitute the 11S globulin gene family (8). There are large variations in copy number of a gene belonging to the 11S globulin gene family and, as expected, plant species with more copies per genome have higher proportion of 11S globulin protein in their seed storage proteins (8), as summarized in Table 1. Rice has 12 copies of glutelin gene, which rival or surpass legumes, and the proportion of glutelin is no less than about 70% in the seed proteins. By contrast, maize and sorghum with a single copy of *legmin 1* and *SORB1*, respectively, contain very small proportion of the protein. Thus, rice grains contain 11S globulins as the major protein as if legumes such as soybeans do. As described above, amino acid score of soybeans is as high as milk and egg proteins

Fig. 3. Rice seed 11S globulin (glutelin) genes are orthologues of soybean 11S globulin (glycinin) genes. The phylogenetic tree is obtained for GY1 gene of Glycine max using glutelin gene of *Oryza sativa* Japonica Group in Ensemble Plants (<http://plants.ensembl.org/index.html>).

Table 1. The content of seed 11S globulins and the copy number of their genes.*

Common name Genus Species	Protein content (% to seed dry weight)	Proportion of 11S globulin in seed total protein	The number of 11S globulin genes	Common name
Lgumes				
Soybean <i>Glycine max</i>	~40%	~40%	6	Glycinin
Castor bean <i>Ricinus communis</i>	~40%	~75%	11	Legumin
Cereals				
Rice <i>Oryza sativa</i>	<10%	~70%	12	Glutelin
Corn/Maize <i>Zea mays</i>	<10%	very small	1	Legumin
Sorghum/Great millet <i>Sorghum bicolor</i>	<10%	very small	1	Legumin

* This table is made according to the data in Reference 8).

Table 2. Traditional rice-flour preparations for Japanese confectionery.

Type of rice	Pre-treatment of grains	Milling condition	Name of flour (in Japanese)	Food made from the flour
Brown rice Ordinary rice	Roasting	dry milling	Brown rice flour (Genmai-ko)	Brown-rice drink
Polished rice Ordinary	—	dry milling	Raw rice flour (Jousin-ko, Jouyou-ko)	Traditional confectionery
Glutinous	—	wet milling	Raw rice flour (Shiratama-ko)	Traditional confectionery
Ordinary	—	wet milling protein removal	Rice strach	Processed food
Glutinous	Steaming and drying or lightly roasting	dry milling	Heat-treated rice flour (Kanbai-ko, Doumyouji, Jounan-ko)	Traditional confectionery
Glutinous	Roasting	dry milling	Heat-treated rice flour (Rakugan-ko)	Traditional confectionery

and, therefore, plant seed 11S globulins including rice glutelin have relatively high nutritional quality among plant-source proteins. High content of legume-type storage proteins, 11S globulins, could be one reason for the relatively higher nutritional quality of rice seed proteins as compared with the quality of wheat and maize, which contain prolamin family proteins such as glutenins, gliadins and zein (6).

3. Rice Flour Consisting of Starch Granules and Protein Bodies

Among various species of cereals, rice seeds have long been ingested mainly as grains, not flour like wheat. In some Asian regions, rice flour is also used for some processed food such as rice noodle and vermicelli. In Japan, rice flour is being used for traditional confectionery such as sweets and cakes. Using several special processing technologies including steaming, drying and roasting before rice milling and milling processes under wet

and dry conditions, different types of rice flour preparations have been developed depending on intended usage (Table 2).

Recently, rice flour became to be utilized for various processed food such as bread and noodle to expand rice utilization. By milling rice grains to flour micro-particles, processing characteristics of rice starch and proteins are changed more or less. For example, globulins can be removed easily from rice flour, but not grains, by simply soaking with salt solution (Fig. 4).

Starch and proteins as the major components of rice grains are accumulated in specific organelles termed amyloplast and protein bodies, respectively in the cells of endosperm and aleurone layer. The endosperm cells contain many amyloplasts with multiple starch granules and protein bodies with glutelins (Protein body II) and prolamins (Protein body I). On the other hand, the cells in aleurone layer contain another type of protein body called aleurone grains with non-storage proteins

Fig. 4. Processing rice grains to flour increases proteins solubilized with salt solution. Flour of polished rice grains were fractionated depending on particle size. Each fraction and intact grains were incubated with salt solution for protein extraction. The proteins extracted from a fixed weight of rice flour or grains were analyzed using SDS-PAGE with CBB staining. Major proteins extracted from rice flour are shown on the right.

and little amyloplasts. Depending on milling conditions and flour particle size, the composition of starch and proteins could be modified. Rice flour particles consist of protein and starch nanoparticles. Especially as for proteins, proportion of glutelin and prolamin contents might be different from flour particle to particle, because the two proteins are stored distinct protein bodies separately. Milling rice grains to flour particles could greatly expand the range of rice-based processed food for prevention of malnutrition and restoration of good health, because flour particles from various different sources can be blended for desired nutritional composition without spoiling the value of product food. As schematically shown in Fig. 5, development of rice flour preparation with desired composition, including macro- and micronutrients and functional phytochemicals, could be expected by properly blending some flour preparations with different component composition from brown rice, polished rice and rice bran of a diversity of rice species and cultivars in the world. Moreover, modification of protein components in rice flour preparations might become possible by future progress of the processing and separation technologies for micro- and nanoparticles in rice flour.

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No conflicts of interest to be declared.

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Fig. 5. Combination of polished rice flour and defatted rice bran for rice flour preparations with desired nutrient composition.

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