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Rice: Importance for Global Nutrition

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Summary Rice, a staple food for more than half of the world's population, is grown in >100 countries with 90% of the total global production from Asia. Although there are more than 110,000 cultivated varieties of rice that vary in quality and nutritional content, after post-harvest processing, rice can be categorized as either white or brown. Regional and cultural preferences as well as need for stability during storage and transport are the final determinants of market availability and final consumption. In addition to calories, rice is a good source of magnesium, phosphorus, manganese, selenium, iron, folic acid, thiamin and niacin; but it is low in fiber and fat. Although brown rice is promoted as being "healthier" because of bioactive compounds, including minerals and vitamins not present in white rice after polishing, white rice is more widely consumed than brown. This is for several reasons, including cooking ease, palatability, and shelf life. Polished rice has a higher glycemic load and may impact glucose homeostasis but when combined with other foods, it can be considered part of a "healthy" plate. With the projected increase in the global population, rice will remain a staple. However, it will be important to encourage intake of the whole grain (brown rice) and to identify ways to harness the phytonutrients that are lost during milling. Furthermore, as the world faces environmental challenges, changing demographics and consumer demands, farmers, healthcare providers, food manufacturers and nutritionists must work collaboratively to assure adequate supply, nutritional integrity and sustainability of rice production systems globally.

Key Words rice, global nutrition, health

Rice (*Oryza sativa*) is a staple food for more than half of the world's population, providing more than 20% of the calories consumed worldwide, especially in East and South Asia, the Middle East, the West Indies and Latin America (*1*). Rice is grown in more than 100 countries with 90% of the total global production from Asian countries. Although it has been reported that there are over 110,000 varieties of rice, *Oryza sativa* is the most widely known and grown (*2*). Rice varies in grain length, color, thickness, stickiness, aroma and growing conditions/production practices that impact "quality" and nutrient profiles. The global market for rice of different varieties is influenced by regional and cultural preferences. Balancing production with the economics of consumer choice and farmer livelihood as well as the environment (land use, water availability, climate) is the challenge facing the rice community because rice as a staple food is likely here to stay.

After harvest and processing, cultivated rice can, in general, be categorized as either white or brown (*3*) with the different characteristics obtained through milling. Some countries prepare unhulled rice which is parboiled. White rice is defined by removal of the bran, with a subsequent loss of some nutrients, including fat, protein, phosphorus, calcium and B-vitamins, and phytochemicals but with the starch endosperm intact (*4*). White rice is a major source of calories but also provides important minerals (e.g. magnesium manganese, selenium, iron and phosphorus) and vitamins (thiamin, niacin, folic acid). The "bioactive" phytochemicals include polyphenols, anthocyanins and flavonoids. Rice bran is rich in compounds such as γ-oryzanol, tocopherol, tocotrienol, amino acids and dietary fibers (*5*). The health implications of consuming rice remain an area of controversy, but with increases in diet-related noncommunicable diseases such as overweight/obesity, Type 2 diabetes mellitus, osteopenia/osteoporosis, cognitive disorders and cancer, it is important that research focuses on what constitutes a "healthy" plate and how to produce it for the growing world population in a sustainable manner. Such efforts should remain at the forefront of government, private and academic efforts.

One of the impacts of rising carbon dioxide (CO_2), in addition to global warming, on food security, is specific to changes in the availability and nutritional quality of rice. In a recent publication, Zhu et al (*6*) reported that higher carbon dioxide concentrations generated in an open-field method called FACE (free-air CO_2 enrichment) were associated with reductions in levels of B vitamins, protein, iron and zinc in 18 different, and widely grown rice cultivars. The health implications for high rice-consuming countries often with the lowest gross domestic product (GDP) are difficult to forecast but raise the concern that the population may be placed at nutritional risk if left unchecked. Efforts to determine whether cultivar selection, either through traditional breed-

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ing or genetic modification, will lead to a nutritionally "superior" rice in the face of rising carbon dioxide are underway.

Beyond effects on plant physiology, rising CO_2 also impacts soil health in rice systems. For example, investigators reported that polycyclic aromatic hydrocarbons (PAHs), well-known organic pollutants, accumulated in paddy soil in the presence of higher CO_2 as a consequence of changes in the soil microbial communities, especially those responsible for PAH degradation (*7*). Fortunately, no significant differences were found in PAH concentration in the rice seeds. However, there are potential implications for CO_2-related food safety and nutritional quality issues as atmospheric CO_2 continues to rise.

The role of rice in the context of nutrition and human health remains a keen area of interest. At the US Department of Agriculture's Dale Bumpers National Rice Research Center, scientists use genomic and genetic resources as well as improvements in agronomic management to advance rice yield and grain quality and to reduce crop losses due to biotic and abiotic stressors. Rice phenolic compounds, particularly the flavonoid subgroup, are secondary metabolites that are thought to be a protective response of plants to these biotic and abiotic stressors and are reported to have multiple health-promoting properties. USDA scientists (*8*) recently reported that purple rice bran accumulated anthocyanins and proanthocyanindins, which are used to modulate inflammatory responses and may protect against Type 2 diabetes mellitus, cardiovascular diseases and some cancers. As interest grows in using food to reduce risk for diseases, it will be important to establish the biological effects and efficacy and consumer acceptance of new rice varieties targeted for biofortification of these bioactive compounds.

In rodent studies, Kumar et al (*9*) investigated the immuno-modulatory capacity of rice bran differing in phytochemical profiles in mice infected with *Salmonella enterica*. Two groups of mice were fed 10% rice bran or a control diet and infected with the bacteria; the largest protection against *Salmonella enterica* colonization was observed with the IAC600 variety and reduced fecal shedding correlated with increased levels of boron, soluble fiber, vitamin E isomers and fatty acids. The authors concluded that rice bran may be a promising functional food but that studies in humans were needed to establish its ability to modulate intestinal immunity and prevent colonization by *Salmonella enterica.* In humans, a randomized-control trial in 38 children (10±0.8 y) at risk for cardiovascular disease was conducted to determine the differential effects of 4 wk of navy bean and rice bran intake on the plasma metabolome (*10*). Results showed that navy bean and/or rice bran consumption influences 71 plasma compounds compared to control with lipids representing 46% of the total plasma metabolome, supporting the hypothesis that consumption of these foods could impact blood lipid metabolism with implications for reducing cardiovascular disease risk. Obviously, these findings need to be confirmed and demonstrated over longer periods with better understanding of the potential mechanisms before causality is established.

In summary, these examples suggest that there may be potential benefits for components of rice beyond meeting caloric needs. However, it is also clear that any benefits must be considered in the context of a changing environment (e.g., rising CO_2). Understanding the effects of environmental change and agricultural practices on rice quality and production are key to ensuring the future of rice as a staple in the global food system.

Disclosure of State of COI

No conflicts of interest to be declared.

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