ELSEVIER

Food Chemistry 80 (2003) 589–596

Food Chemistry

www.elsevier.com/locate/foodchem

Analytical, Nutritional and Clinical Methods

Analysis of food composition data on rice from a plant genetic resources perspective

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Received 20 April 2002; received in revised form 23 September 2002; accepted 23 September 2002

Abstract

Rice accounts for 21, 14 and 2% of global energy, protein and fat supply, respectively. There are thousands of different rice varieties; some have been in the diet for centuries, while others are new hybrids promoted for qualities such as high yield and drought and disease resistance. Little is known about the nutrient composition of many of the world's rice varieties. This paper investigates the literature on nutrient composition of rice varieties. Standardization of data to 100 g samples of unpolished rice (dry matter basis), showed intra-varietal ranges of; 9 g protein, 5.65 mg iron, 3.34 mg zinc, 1.6 mg thiamin, 0.392 mg riboflavin and 7.2 mg niacin. Currently, several research institutions are working toward improving the nutrient content of rice through greater utilization of rice genetic resources. The results section discusses in detail the magnitude of intra-varietal differences and highlights practical applications of genetic diversity in rice.

Keywords: Rice; Varieties; Nutrient composition; Plant genetic diversity; Micronutrients

1. Introduction

Rice accounts for 21, 14 and 2% of global energy, protein and fat supply, respectively. Rice is the predominate staple for 15 countries in Asia and the Pacific, ten countries in Latin America and the Caribbean, one country in North Africa and seven countries in Sub-Saharan Africa (FAO, 1999). In developing countries, rice accounts for 715 kcal/capita/day; 27% of dietary energy supply, 20% of dietary protein and 3% of dietary fat. Countries in Southeast Asia are heavily reliant upon rice; in Bangladesh, Laos, Viet Nam, Myanmar and Cambodia, rice supplies more than 50% of per capita dietary energy and protein and 17–27% of dietary fat. In Guinea, Gambia, Senegal and Cote d'Ivoire, rice supplies between 22 and 35% of dietary energy and 23–34% of dietary protein (FAOSTAT, 2001).

The first attempts to cultivate rice occurred around 10,000 years ago (FAO, 2000). Since that time farmers and more recently rice breeders, have manipulated the crop for desired characteristics. Beginning in the 1920s a focus on increasing the yield potential of rice emerged (FAO, 2000). This focus was intensified over the next decades due to increasing population pressure, and the desire to render cultivated land more productive. Through these attempts several high yielding rice varieties were established. It is these varieties that dominate current rice markets. Despite the world's heavy reliance on rice, the genetic resource base of rice is dwindling (Shastry, Tran, Nguyen, & Nanda, 1996). Table 1 demonstrates that there were once thousands of rice varieties cultivated; this genetic diversity has eroded to less than 100 cultivars in any given country.

Increasing land pressure, indiscriminate use of fertilizers and pesticides and destruction of much of the world's forested areas have contributed to the decline in the world's plant genetic resources (Paroda, 1999). The influence of modern agricultural practices and focus on high-yield crop varieties has been another contributing factor (IRRI, 2001).

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0308-8146/03/$ - see front matter
PII: S0308-8146(02)00507-1

Table 1
Extent of genetic uniformity in rice

Country	Number of varieties grown		
	Past	Present	Remark
Bangladesh	5000	23	
Japan	1302	–	70% Of area cultivated under three varieties
Korea	4227	12	
Philippines	–	13	
Sri Lanka	2000	100	
Taiwan	1679	50	> 82% Of area cultivated under three varieties
Thailand	16185	37	50% Of area cultivated under two varieties

Source: Paroda (1999).

2. Modern and conventional agricultural approaches to improve the nutritional value of rice

Historically, the nutrient content of staple foods was not a focus of plant breeders and others in the agricultural sector (Ruel & Levin, 2000). Recently, breakthroughs in scientific technology and increasing concern over the high global prevalence of micronutrient malnutrition, has lead toward a new focus on the micronutrient density of staple crops. Globally, there is a large prevalence of micronutrient malnutrition. Vitamin A, iron and iodine deficiency are the most wide spread and devastating forms of micronutrient malnutrition (UNICEF, 1998). The most widely consumed staple crops—rice, wheat and maize—are not good sources of these nutrients. Yet for the poor who lack access to diverse foods, staple crops are their main source of micronutrients (Bouis, 1996). The coalescence of these factors has sparked new possibilities and challenges for the agriculture and nutrition sciences.

Scientific progress in the area of genetic mapping has made it possible to genetically alter the bio-chemical structure of plants by utilizing the genes of diverse plant species. ''Nutritional genomics'', is a term used to define a combination of biochemistry, genetics, molecular biology and genome-based technologies used to manipulate the synthesis of plant compounds that have nutritional value (Tian & DellaPenna, 2001). One application of this approach is to enhance existing biosynthetic pathways. Using this technique, researchers at Michigan State University achieved a 10-fold increase in the vitamin E content of experimental plants (Tian & DellaPenna, 2001). A different application of this technology is transgenetic manipulation, which introduces a completely new biosynthetic pathway into the plant. The most widely known application of this technology is ''golden rice''. Using a combination of biosynthetic pathways from other plant materials, the entire β-carotene biosynthetic pathway, which does not naturally exist in rice, was introduced into rice endosperm. This experiment produced a rice plant with rice grains containing 1.6 μg/g of carotenoid (Ye et al., 2000). Another project on rice focused on increasing both the iron content of the grain and the bioavailability of the iron once ingested. Similar to the manipulation used to develop golden rice, a two-fold increase in iron content was achieved by transferring the coding sequence of ferritin from a bean (*Phaseolus vulgaris)* into rice endosperm. At the same time to increase the bioavailability of the iron, a phytase gene from the common mold *Aspergillus fumigatus* was inserted to break down phytic acid which binds to iron (Lucca, Wunn, Hurrell, & Potrykus, 2000). Other researchers are making progress in their investigations of rice low phytic acid (lpa) mutants, and through using the tools of biotechnology they can substantially reduce the phytic acid portion of seed phosphorus (Larson, Rutger, Young, & Raboy, 2000).

The potential for improving the micronutrient density of staple foods through these new technologies is not the only agricultural option for widespread increases in the nutritional value of staple crops. DellaPenna argues that, while these new technologies should be pursued, the value of utilizing existing plant genetic resources to achieve crop improvements through conventional breeding techniques should not be abandoned (DellaPenna, 1999). The same methods used to develop high yielding rice varieties can be similarly employed to improve micronutrient density. The basic information required is the nutrient composition and range of intraspecies diversity. This information can then be used to develop nutritionally improved cultivars.

While both of the above mentioned strategies have promise, the potential to efficiently utilize existing intraspecies diversity should be fully explored and developed. Rural farmers have long understood the importance of diverse plant genetic resources for the well being of their crops and food security of their families (Joshi, Subedi, Rana, Kadayat, & Sthapit, 1997). Traditionally, several varieties of the same crop were cultivated, with the knowledge that at least one or two of the varieties could produce food, given just about any environmental challenge (IRRI, 1999). As will be illustrated later in the paper, there are multiple advantages to be gained from better utilization and conservation of the wide range of existing genetic material.

3. Genetic diversity in rice

Rice is from the genus *Oryza* and is comprised of 21 species, only two of which are cultivated: *Oryza sativa and Oryza glaberrima* (Juliano, 1985). *Oryza sativa* is believed to have originated in Southeast Asia, while *Oryza glaberrima* originated in West Africa. Today, nearly all of the thousands of rice varieties grown and developed originated from *Oryza sativa*. *Oryza sativa* can be divided into three sub-species, *indica, japonica* and *javanica*. *Indica* and *japonica* sub-species are the most common, with *indica* variety representing 80% of all cultivated rice (Malik & Chaudhary, in press). *Indica* varieties are common in tropical regions, as many are drought tolerant but do not tolerate colder temperatures. The grains are medium to long, narrow and flat (FAO, 2000). *Japonica* varieties are more tolerant to cold temperatures, but less tolerant to drought, insects and disease (FAO, 2000). The grains of japonica varieties are short and wide. Glutinous (''sticky'') and non-glutinous varieties exist for all sub-species. The amylose content is a major determinate of the stickiness of rice. Rice with low amylose content is sticky; as the amylose content increases, the rice becomes firmer. *Japonica* varieties tend to have lower amylose content than the *indica* varieties (FAO, 2000).

4. Methods (compilation of nutrient composition data of rice by variety)

A thorough literature search was performed to gather existing information on nutrient composition of rice by variety. While many environmental and post harvest factors, such as solar radiation, irrigation, milling, preparation and cooking can influence the ultimate degree of nutrition derived from rice, this review focuses on the measurable differences within varieties, best assessed from dry matter analysis. National Food Composition tables were searched, as were nutrition and agriculture journals. Often in food composition tables where nutrient composition is comprehensive, milling level and cooked or raw state is recorded, but varietal name is not. The Chinese food composition table is the main exception, with many varieties listed. Studies that compare one variety with another commonly focus on a specific macro or micronutrient such as protein or zinc and do not provide complete nutrient analysis. In agricultural research, the protein and amylose content of thousands of rice varieties has been analyzed as these two nutritional factors can considerably alter consumer preference (Unnevehr, Duff, & Juliano, 1992).

4.1. Data sources

Food composition tables from China, Korea, Malaysia, Nepal, Pakistan, the Philippines, Thailand and the United States, all provided some information on the variety (or type) of rice analyzed (Food and Nutrition Research Institute, 1997; Government of Pakistan Ministry of Planning and Development, 1985; Ministry of Agriculture Nepal, 1994; National Rural Living Institute, 1996; Puwastein, Raroengwichit, Sungpuag, & Judprasong, 1999; Siong, Noor, Azudin, & Idris, 1988; US Department of Agriculture, 2001; Wang, Parpia, & Wen, 1997). Often, the specific varietal name was not recorded, but there was enough of a description to be able to classify the rice as long, medium or short grained, of a glutinous or non-glutinous nature, with particular emphasis placed on the color of the pericarp. A series of journal articles and book chapters containing some nutrient information by variety were also found (Chandrasekhar & Mulk, 1970; Deosthale & Pant, 1970; di Baldi, Malagoni, Pela, & Ranghino, 1974; Dutta & Barua, 1978; FAO, in press; Matthews, Wadsworth, & Spadora, 1981; Senadhira, Gregorio, & Graham, 1998; Sotelo, Sousa, Montalvo, Hernandez, & Hernandez-Aragon, 1990; Toyoshima et al., 1994; Toyoshima, Okadome, Yoshizahi, Kimura, & Ohtsubo, 1999; Villareal & Juliano, 1989; Wahid, Hussain, Baksh, & Rehman, 1975). A book by Juliano and Villareal (1993) itemized the protein and amylose content of several thousand rice varieties.

4.2. Nutrient identification—methods and expressions

Significant difficulty was encountered in standardizing the data for comparison across varieties. In the literature, numerous conversion factors and expressions were used. For example, some sources used 5.95 as the nitrogen to protein conversion factor while others used 6.25. The variation in units used to calculate micronutrient composition was extensive. Some of the units encountered were μg/g, mg/g, mg/100 g, mg/kg, mg/100 kg,%,% dmb, ppm and ‰. In order to draw comparisons between varieties across numerous data sources, only raw, unpolished samples were compared. All nutrients were standardized to g/100 g dry matter, in the case of proximates and mg/100 g dry matter for vitamins and minerals. Differences in the data reported in this paper and those found in the source materials, result from these recalculations.

5. Results—varietal differences in nutrient composition

Varietal differences in nutrient composition were found for every nutrient. The magnitude of the differences between varieties was great, with certain varieties containing nutrient densities three to four times greater than the reported average. The relative importance of the difference depends on the nutrient. For example, certain varieties of rice contained 3–4 mg more iron than the average value, enough to make a nutritionally significant contribution to intake.

The number of varieties compared was dependent on the nutrient under review. Food composition tables provided the most extensive nutrient profile for any one variety, while other sources provided information on a large number of varieties, but for only one or two nutrients. Results for protein, iron, zinc, calcium, thiamin, riboflavin and amylose are presented in this section. Certain large sources of data recorded information by variety for two nutrients for example, iron and zinc, or thiamin and riboflavin. These established groupings were retained in this review in order to avoid repetition of varietal names.

5.1. Protein

Protein is the most common nutrient analyzed in rice and protein content was found to differ significantly by variety (Chandrasekhar & Mulk, 1970; Gomez, 1979; Juliano & Villareal, 1993) The International Rice Research Institute (IRRI) analyzed the protein content of 2869 rice varieties. Table 2 provides a review of the protein content of 2674 *Oryza sativa* varieties and 195 *Oryza glaberrima* varieties analyzed at the IRRI laboratory. Protein content[1] ranged from 4.5 to 15.9% in *Oryza sativa* varieties and 10.2–15.9% in *Oryza glaberrima* varieties. Asian rice varieties from *Oryza sativa* exhibited the greatest overall variation in protein content (4.5–15.9%), while *Oryza glaberrima* varieties had the highest average protein content (13.6%).

An additional database of 200 varieties, prepared from food composition tables and current literature found a similar protein range (5.55–14.58 g/100 g dry matter basis) with an average protein content of 8.55 g/100 g. The width of the range between the highest and lowest protein content was 9 g. The variety with the highest protein content was 1.7 times greater than the average protein content. The variety with the highest recorded protein content was in Chinese, fragrant, long grain rice; the lowest recorded value was from the Japanese variety *Koshihikari*.

5.2. Micronutrients

5.2.1. Iron and zinc

Iron content has been reported for 95 varieties. The range in iron content was 0.70–6.35 mg/100 g with an average of 2.28 mg/100 g dry matter basis. The range between the highest and lowest iron values was 5.65 mg, with the highest variety being 4 g higher than the average. The highest iron content recorded was in long grained red rice from the Chinese food composition table (Wang et al., 1997).

Fifty-seven varieties had nutrient composition for zinc. The range for zinc was 0.79–5.89 mg/100 g with an average of 3.34 mg/100 g dry matter basis. The difference between the highest and lowest zinc content was 5.1 g; the highest recorded variety being 2.5 g higher than the average. The largest zinc value was found in Ganjay Roozy, a variety grown at IRRI while the lowest zinc value recorded was in long, grain fragrant rice from the Chinese food composition table (Senadhira et al., 1998; Wang et al., 1997).

A sample of varieties grown under greenhouse conditions at IRRI is presented in Table 3. This table demonstrates that some traditional rice varieties contain 2.5 times more iron than the commonly grown high yielding varieties. Four of the five varieties richest in iron and zinc are traditional rice varieties, while the varieties at the lower end of the scale in terms of iron and zinc content are the popular, modern high yielding varieties. A trait for high iron and zinc has been linked to aromatic varieties such as jasmine and basmati (Graham, Welch, & Bouis, 2001). Of note is the observation that screening tests run to identify germplasm with high iron and zinc found a statistically significant

Table 2
Summary by region of protein content in milled rices

Source	Sample number	Protein range (%)	Protein mean (%)
O. sativa L.			
Asia	1626	4.5–15.9	8.7
Australia	24	5.7–11.4	7.6
North America	190	4.5–14.8	8.2
South America	301	5.7–14.8	9.0
Europe	233	5.7–14.8	8.0
Africa	300	5.7–12.5	8.3
Total	2674	4.5–15.9	8.8
O. glaberrima	195	10.2–15.9	13.6

Source: adapted from Juliano and Villareal (1993).

[1] The protein content of the IRRI varieties was originally based on 12% moisture (Juliano personal communication). The protein content was recalculated to a dry matter basis for this analysis.

Table 3
Iron and zinc content of selected varieties grown in greenhouse conditions (Average of three replications)

Variety	Iron mg/100 g	Zinc mg/100 g
Ganjay Roozy	2.64	5.89
Zuchem	2.34	5.10
YR 4194	2.32	5.40
Banjaiman	2.27	5.30
Xue Bue Nuo	2.25	4.66
IR 64446	2.22	5.35
Kinmaze	2.17	5.17
Tsuyake	2.12	4.25
CNA 6187	2.07	5.45
Miyazaki 7	2.03	4.25
Ketan Irang	2.02	5.53
CT7127	2.01	4.70
Huri 370	1.98	4.57
Lagrosa	1.80	4.82
Ketan Menah	1.61	4.54
IR 10198	1.58	3.79
Skybonnet	1.53	4.13
IR 60864	1.50	4.11
Heibao	1.49	3.16
Alan	1.40	3.92
IR 63877	1.31	3.64
IR 74	1.30	3.64
IR 72	1.17	3.25
IR 36	1.01	3.14

Source: adapted from Senadhira et al. (1998).

Table 4
Thiamin, riboflavin and niacin content of selected rice varieties

	Thiamin mg/100 g ($n=79$)	Variety	Riboflavin mg/100 g ($n=80$)	Variety	Niacin mg/100 g ($n=30$)	Variety
Min.	0.117	Jaya	0.011	Mun-pu red	1.972	Glutinous round grained
Max.	1.74	Juchitan A-74	0.448	Tapol	9.218	Long grained purple
Average	0.475		0.091		5.322	

correlation with phytate: as the iron and zinc contents increased, so did the phytate (Graham, Senadhira, Beebe, Iglesias, Monasterio, 1999). The nutritional implications, regarding the bioavailability of the increased iron and zinc content counterbalanced with increased phytate are still under investigation. The potential for combining the positive characteristics of the traditional nutrient dense varieties with the high yielding traits of the modern, popular varieties is being explored (Graham, Senadhira, & Ortiz-Monasterio, 1997).

5.2.2. Calcium

The calcium content was reported for 57 varieties. Calcium content ranged from 1 to 65 mg/100 g dry basis with an average content of 26 mg/100 g. The highest value recorded was for variety ADT-21, from an analysis of red rice varieties in India (Deosthale & Pant, 1970).

5.2.3. Thiamin (B1), riboflavin (B2) and niacin

Table 4 describes the range of thiamin, riboflavin and niacin recorded. The reported range of thiamin in 79 varieties was 0.117–1.74 mg/100 g, with an average of 0.457 mg/100 g, the greatest difference between varieties being 1.6 mg. Riboflavin ranged from 0.011 to 0.403 mg/100 g and averaged 0.087 mg/100 g, with a difference between the highest and lowest varieties of 0.392 mg/100 g. Niacin had a range of 1.972–9.218 mg/100 g an average of 5.322 mg/100 g and a 7.2 mg difference between the highest and lowest varieties. The highest thiamin content was in a Philippine dark purple variety *Tapol,* riboflavin content was greatest in a Mexican variety *Juchitan A74*, and the highest niacin content was in Chinese long grain, purple rice (Villareal & Juliano, 1989; Sotelo et al., 1990; Wang et al., 1997).

Villareal and Juliano (1989) studied the variation in thiamin and riboflavin content of 30 varieties developed at IRRI and five pigmented traditional Philippine rice varieties. The range in thiamin content of the IRRI varieties was 0.285–0.52 mg/100 g wet basis (converted from μg/g) and 0.33–0.46 mg/100 g for the pigmented varieties. Variety had a significant influence on both thiamin and riboflavin content. Results for the five traditional varieties are presented in Table 5. When compared to the IRRI varieties, the Philippine varieties had similar thiamin content, while the varieties with darker colored pericarp had higher riboflavin content.

5.3. Amylose

Amylose and amylopectin are the two polysaccharide starch components found in carbohydrates (FAO, 1998). The amylose content in rice can dramatically influence consumer preferences, and has therefore achieved great importance from the rice breeders' point of view. Due to the influence of this starch component there is a wide array of agricultural literature published on the amylose content of rice varieties. As with other nutrient components of rice, amylose content of the grain is influenced by the rice variety (Unnevehr et al., 1992). Amylose content is classified as waxy, 1–2%; low, 7–20%; intermediate, 20–25%; and high >25% (Juliano, 1985). The range of amylose content of over 2000 varieties was 0.5–33 mg/100 mg. Table 6 provides a listing of the varieties with the highest and lowest amylose content.

When cooked, rice with low amylose content is sticky and soft, as amylose content increases, rice becomes firmer. Consumers in South Asia and the Middle East prefer dry flaky rice, while in Japan, Taiwan, Korea, Egypt and north China moist, sticky rice is preferred (Malik & Chaudhary, in press).

In addition to influencing consumer preferences, the amylose content of rice has been shown to influence the glycemic index of a food, and have health implications. The glycemic index (GI) is a basic ranking of how quickly a food raises blood sugar in a test subject, when compared to either glucose or white bread (standardized to an index of 100). High GI foods raise blood sugar quickly, while low (GI) foods raise blood sugar gradually. The glycemic index of foods is often used to provide dietary counseling to control diabetes and obesity, as foods with low GI have been associated with lower

Table 5
Thiamin and riboflavin content of five traditional rice varieties (mean of duplicate samples)

Variety	Color of pericarp	Thiamin mg/100 g	Riboflavin mg/100 g
Azucena	Pink	0.42	0.082
Carreon	Pinkish-red	0.33	0.105
Makapilay-Pusa	Red	0.42	0.132
Pirurutong	Dark purple	0.36	0.267
Tapol	Dark purple	0.46	0.403

Source: Villareal and Juliano (1989).

Table 6
Apparent amylose content of selected rice varieties (analysis of single samples)

Name of variety	Country	Apparent amylose content % (dry matter basis)
		Lowest
Malagkit	Philippines	0.5
Pulut Siding	Malaysia	0.8
Bpi-Ri-1	Philippines	0.9
Bpi-Ri-3	Philippines	0.9
Shuang-nuo 4	China	1.2
		Highest
IR 8	Philippines	33.0
Peta	Philippines	32.8
Yogaga	Ghana	32.8
No. 79	Guyana	31.8
Kolamba 42	India	31.6
Kolamba 540		
Karjat 184		

Source: Juliano and Villareal (1993).

blood glucose, insulin and lipid levels (Wolever, 1990). Research on the glycemic index of rice has shown that amylose content is negatively correlated with glycemic index; the higher the amylose content of rice, the lower the glycemic index and insulin index (Miller, Pang, & Bramall, 1992). Studies on healthy volunteers, found lower serum glucose and insulin levels when high compared to low amylose rice was consumed (Goddard, Young, & Marcus, 1984). The large variation in the amylose content of rice by variety, and the health implications associated with amylose content, highlight the importance of analyzing varietal differences in nutrient composition.

6. Practical applications of rice genetic diversity

Preserving rice genetic diversity can be seen as a positive action in its own right. Additional incentive is provided given the global reliance on this important food staple. There is clear additional value to be gained from protecting the genetic source codes which hold the key to future varietal improvements. Improvements, which can be realized in both the fields of nutrition and agriculture. Current practical applications of rice plant genetic resources are numerous.

6.1. Nutritional applications

Combining the traits of high nutrient content and high yield through conventional breeding techniques has the potential for substantial nutritional impact. At IRRI a rice variety was created by breeding together varieties with high zinc and iron content with varieties containing traits for improved yield. The bioavailability of the increased iron and zinc in this new variety will be tested in a controlled trial in early 2002 (IRRI, 2001).

Classifying rice varieties as high or low glycemic index foods has obvious health and nutrition applications and was advocated by the last expert consultation on carbohydrates in human nutrition (FAO, 1998).

6.2. Agricultural applications

An experiment carried out by rice researchers and rice farmers in the Yunnan province of China demonstrated the value added of utilizing diverse rice genetic resources. Experimental plots were planted with either a single high yielding variety or with the popular high yielding variety mixed with hardier, disease resistant, traditional varieties. Plots where both modern and traditional rice were planted together had 89% greater yield and less severity of rice blast (a fungal disease) than monoculture plots (Zhu et al., 2000). After two years of within-field varietal diversification, application of fungicidal spray was no longer necessary. The environmental and economic benefits of this finding are substantial. It is planned to implement this same strategy in Thailand, the Philippines and Vietnam to reduce farmers' reliance on environmentally damaging pesticides and fungicides (IRRI, 2001).

A similar application combining positive genetic characteristics of different varieties has been achieved at WARDA (West African Rice Development Association). Using conventional and modern techniques scientists at WARDA were able to successfully breed the beneficial traits of both *Oryza glaberrima* and *Oryza sativa* into new varieties. By combining the beneficial traits of the African and Asian species, these varieties have the potential for higher yields, better resistance to disease and drought and higher protein content than the *Oryza sativa* varieties commonly grown in the region (WARDA, 1999). It is hoped that the new varieties will be able to sustain high yields while requiring less fertilizer and pesticide. WARDA has taken a unique and innovative approach toward introducing the new varieties into communities. Projects are underway throughout West Africa to introduce the new varieties to local farmers through a strategy of "participatory varietal selection" techniques.

7. Conclusion

This review has demonstrated that there are large differences in nutrient composition within varieties of rice. However, many of the varieties with higher nutrient content are less favored in the current yield driven market. Too often, nutritional considerations rank far lower than other aspects of crop production. Nutritionists, dieticians and health educators are in part responsible for this, due to a lack of interest and attention drawn to differences within crop varieties. There is no reliable, comprehensive source for accessing nutritional data on the varietal level. A concerted effort should be made to incorporate varietal level information when conducting dietary intake surveys, compiling food composition data and providing dietary guidance. Food composition tables are the ideal entry point for providing access to researchers and the public on the nutritional value of different crop varieties. Currently, this information is not provided in most national food composition tables. Agricultural research organizations, such as IRRI and other CGIAR centers also play a valuable role in highlighting the benefits of varietal differences among major crops, these efforts should include analyzing nutritional differences within species. There is a wealth of genetic diversity in rice with a largely untapped potential. As we begin the twenty-first century, the challenge of reducing malnutrition remains great. Increasing our knowledge, use and application of existing, diverse plant genetic resources can positively contribute to nutritional improvements.

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