**RICE IN ASIAN COUNTRIES**

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4. **INTRODUCTION**

Beyond the production level, little is known about **what**, **where** and **how** key commodities are transformed and - more importantly - how much is being made available for food consumption and in what form.

The **scope of this research is to study selected staple food commodities in particular regions to develop guidelines for monitoring food security at country level**. The idea is to survey agents in value chains for staples who are present at the farmgate at the time of harvest and are engaged in buying the crops for particular markets, e.g. retail, feed, food processing and alcohol, and how much of the staple is retained by the farmer for seed and storage. The survey can also be implemented in conjunction with other surveys, namely on production, to ensure low cost and sustainability.

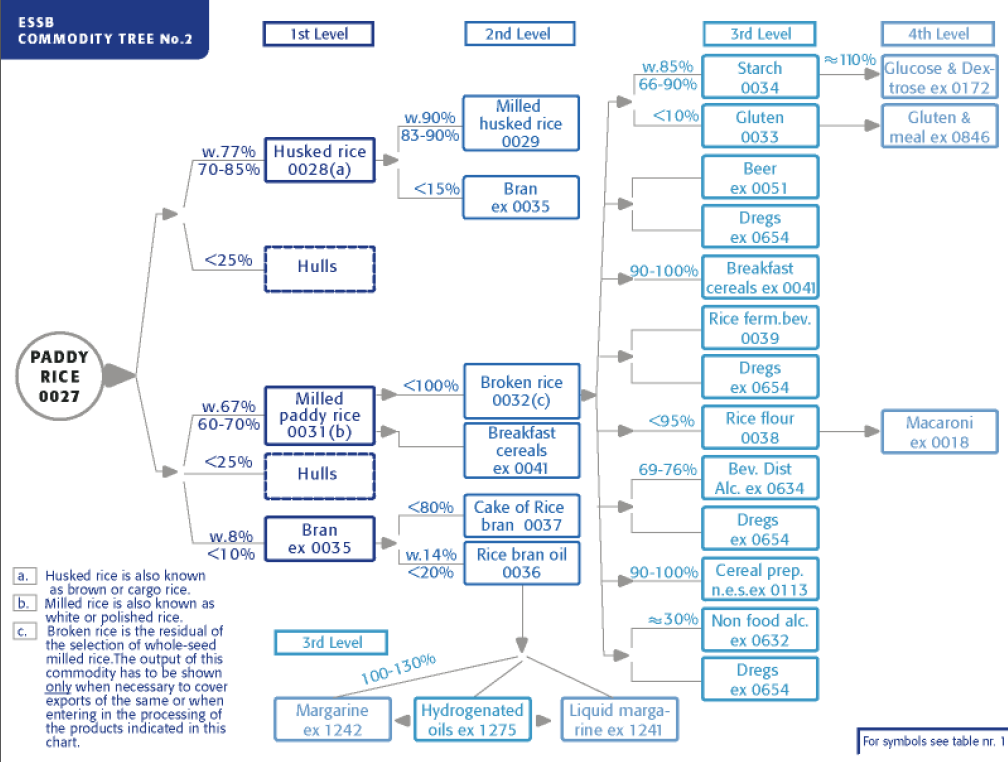
The analysis is based on physical characteristics, ways of utilization and storage, and traditional vs industrial methods to transform raw commodities into processed food. This should provide us with more detailed information on nutritional characteristics of staple food in relevant regions and what should be targeted.

In order to proceed in this research, information has been collected on major staple foods, and notes have been drafted on crops and their transformation process. Starting from the structure of FAO Commodity Trees[[1]](#footnote-1), research has been conducted on (i) crop characteristics, plant anatomy and nutritive factors, for which different nutrition sources have been compared (e.g. West African Food Composition Tables, United States Department of Agriculture Agricultural Research Service Database[[2]](#footnote-2), ESS Nutritive Factors list[[3]](#footnote-3), etc.); and (ii) processed product transformation: how these primary commodities are transformed into processed food, nutritional characteristics, local recipes, etc.

In order to identify the importance of the commodities in diets and in key countries, data on *food supply* (kcal/capita/day), *protein supply quantity* (g/capita/day) and *fat supply quantity* (g/capita/day) have been downloaded from the FAOSTAT for the following crops: cassava, rice, rice, oats, rice milled, rice paddy, sorghum, soybean and wheat. For each country, the commodity supply on total food supply has been calculated, and the average for the last three available years (2007-2009) has been considered to rank results and identify where single commodities have a higher impact on total food supply.

Based on that information, countries and commodities have been selected, and what came to light is that **rice** is one of the most important staple foods in Asia.

Rice is in the family of cereals, it is particularly relevant in diet for population in **Bangladesh**, **Cambodia** and **Lao People's Democratic Republic**.

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The *rice supply* in Bangladesh is around the **70%** of the *total food supply* share (average 2007-2009).

The *total* *rice production* for the same country amounts at **46,022,333** tonnes (average 2007-2009), around **68%** of total crop food production in Bangladesh (Table 1).

**Table 1: Rice production and rice supply in Guatemala (FAOSTAT DATA)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice Supply, Bangladesh (kcal/capita/day)** | | |  | **Total Food Supply, Bangladesh (kcal/capita/day)** | | |  |  |
| **2007** | **2008** | **2009** | **Rice average supply (2007-2009)** | **2007** | **2008** | **2009** | **Total food average supply (2007-2009)** | **Rice supply/ Total supply (2007-2009)** |
| 1,741 | 1,664 | 1,727 | **1,710.67** | 2,455 | 2,378 | 2,481 | **2,438** | **70%** |
| **Rice Production, Bangladesh (Tonnes)** | | |  | **Total Food Production, Bangladesh (Tonnes)** | | |  |  |
| **2007** | **2008** | **2009** | **Rice average production (2007-2009)** | **2007** | **2008** | **2009** | **Total food average production (2007-2009)** | **Rice production/ Total production (2007-2009)** |
| 43,181,000 | 46,742,000 | 48,144,000 | **46,022,333** | 63,624,677 | 70,189,062 | 69,128,033 | **67,647,257.33** | **68%** |

The *rice supply* in Cambodia is around the **64%** of the *total food supply* share (average 2007-2009).

The *total* *rice production* for the same country amounts at **7,162,781** tonnes (average 2007-2009), around **54%** of total crop food production in Cambodia (Table 2).

**Table 2: Rice production and rice supply in Mexico (FAOSTAT DATA)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice Supply, Cambodia (kcal/capita/day)** | | |  | **Total Food Supply, Cambodia (kcal/capita/day)** | | |  |  |
| **2007** | **2008** | **2009** | **Rice average supply (2007-2009)** | **2007** | **2008** | **2009** | **Total food average supply (2007-2009)** | **Rice supply/ Total supply (2007-2009)** |
| 1,521 | 1,529 | 1,530 | **1,526.67** | 2,372 | 2,373 | 2,382 | **2,375.67** | **64%** |
| **Rice Production, Cambodia (Tonnes)** | | |  | **Total Food Production, Cambodia (Tonnes)** | | |  |  |
| **2007** | **2008** | **2009** | **Rice average production (2007-2009)** | **2007** | **2008** | **2009** | **Total food average production (2007-2009)** | **Rice production/ Total production (2007-2009)** |
| 6,727,000 | 7,175,473 | 7,585,870 | **7,162,781** | 11,689,429 | 13,721,750 | 14,812,863 | **13,408,014** | **54%** |

The *rice supply* in Lao People's Democratic Republic is around the **62%** of the *total food supply* share (average 2007-2009).

The *total* *rice production* for the same country amounts at **2,941,586** tonnes (average 2007-2009), around **40%** of total crop food production in Lao People's Democratic Republic (Table 3).

**Table 3: Rice production and rice supply in Honduras (FAOSTAT DATA)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice Supply, Lao People's Democratic (kcal/capita/day)** | | |  | **Total Food Supply, Lao People's Democratic  (kcal/capita/day)** | | |  |  |
| **2007** | **2008** | **2009** | **Rice average supply (2007-2009)** | **2007** | **2008** | **2009** | **Total food average supply (2007-2009)** | **Rice supply / Total supply (2007-2009)** |
| 1,424 | 1,450 | 1,465 | **1,446.33** | 2,287 | 2,327 | 2,377 | **2,330.33** | **62%** |
| **Rice Production, Lao People's Democratic (Tonnes)** | | |  | **Total Food Production, Lao People's Democratic (Tonnes)** | | |  |  |
| **2007** | **2008** | **2009** | **Rice average production (2007-2009)** | **2007** | **2008** | **2009** | **Total food average production (2007-2009)** | **Rice production/ Total production (2007-2009)** |
| 2,710,050 | 2,969,910 | 3,144,800 | **2,941,586.667** | 6,740,626 | 7,417,159 | 8,055,675 | **7,404,486.667** | **40%** |

1. **COMMODITY CHARACTERISTICS[[4]](#footnote-4)**

**The origin of rice[[5]](#footnote-5)**

Rice (*Oryza sativa*) is the most important cereal crop in the developing world and is the staple food of over half the world's population. It is generally considered a semi-aquatic annual grass plant. About 20 species of the genus *Oryza* are recognized, but nearly all cultivated rice is *O. sativa* L. A small amount of *Oryza glaberrima*, a perennial species, is grown in Africa. So-called "wild rice" (*Zizania aquatica*), grown in the Great Lakes region of the United States, is more closely related to oats than to rice.

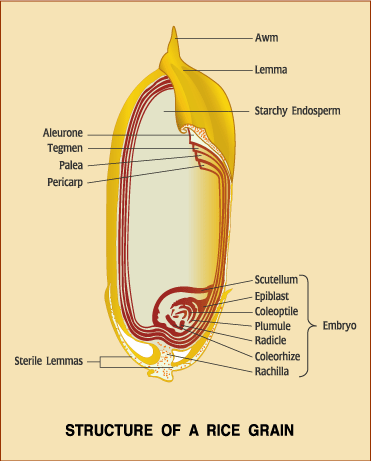
Because of its long history of cultivation and selection under diverse environments, *O. sativa* has acquired a broad range of adaptability and tolerance so that it can be grown in a wide range of water/soil regimens from deeply flooded land to dry hilly slopes (Lu and Chang, 1980). In Asia, cultivars with resistance to aluminum toxicity and with tolerance to submergence by flood water (IRRI, 1975), (Figure 1), high salinity and cool temperatures at the seedling or ripening stage have been developed (Chang, 1983). In Africa, cultivars with tolerance to iron toxicity and heatconstraints have also been developed and cultivated. Rice is now grown in over 100 countries on every continent except Antarctica, extending from 50° north latitude to 40° south latitude and from sea level to an altitude of 3 000 m.

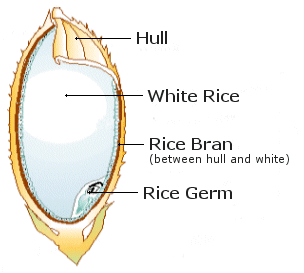
Rice is not only important for food security, but is also an important economic commodity, a crop that consumes a lot of water and contributes to significant amount of greenhouse gasses.

**Rice diversity is furthermore important for plant breeding and nutritional security**, and rice fields host a wide range of terrestrial and aquatic biodiversity.

**2.1 RICE PHISICAL DESCRIPTION AND SPECIES**

**Anatomy: rice grains and their structure[[6]](#footnote-6)**





The rice grain (rough rice or paddy) consists of an outer protective covering, the hull, and the rice caryopsis or fruit (brown, cargo, dehulled or dehusked rice). Brown rice consists of the outer layers of pericarp, seed-coat and nucellus; the germ or embryo; and the endosperm. The endosperm consists of the aleurone layer and the endosperm proper, consisting of the subaleurone layer and the starchy or inner endosperm. The aleurone layer encloses the embryo. Pigment is confined to the pericarp[[7]](#footnote-7).

The hull (husk) constitutes about 20% of the rough rice weight, but values range from 16% to 28%. The distribution of brown rice weight is pericarp 1% to 2%, aleurone plus nucellus and seed-coat 4% to 6%, germ 1%, scutellum 2% and endosperm 90% to 91% (Juliano, 1972).

The aleurone layer varies from one to five cell layers; it is thicker at the dorsal than at the ventral side and thicker in short-grain than in long-grain rices (del Rosario et al., 1968). The aleurone and embryo cells are rich in protein bodies, containing globoids or phytate bodies, and in lipid bodies (Tanaka et al., 1973; Tanaka, Ogawa and Kasai, 1977).

The endosperm cells are thin-walled and packed with amyloplasts containing compound starch granules. The two outermost cell layers (the subaleurone layer) are rich in protein and lipid and have smaller amyloplasts and compound starch granules than the inner endosperm. The starch granules are polyhedral and mainly 3 to 9 ,µm in size, with unimodal distribution. Protein occurs mainly in the form of spherical protein bodies 0.5 to 4 µm in size throughout the endosperm (del Rosario et al., 1968; Bechtel and Pomeranz, 1978) but crystalline protein bodies and small spherical protein bodies are localized in the subaleurone layer. The large spherical protein body corresponds to PB -I (Tanaka et al., 1980) and the crystalline protein body is identical to PB-II. Both PB-I and PB-II are distributed throughout the rice endosperm.

Non-waxy rice (containing amylose in addition to amylopectin) has a translucent endosperm, whereas waxy (0 to 2% amylose) rice has an opaque endosperm because of the presence of pores between and within the starch granules. Thus, waxy grain has about 95 to 98% the grain weight of non-waxy grain.

**Rice classification**

There is no international standard for brown rice grain size and shape. IRRI uses the following scale for size: extra long, >7.50 mm; long, 6.61 to 7.50 mm; medium, 5.51 to 6.60 mm; and short, <5.50 mm. Grain shape is characterized based on length-to-width ratio: slender, >3.0; medium, 2.1 to 3.0; bold 1.1 to 2.0; and round, < 1.0.

The Codex Alimentarius Commission committee considering the draft standard for rice proposed the following classification of milled rice based on length-towidth ratio; long grain, <3.1; medium grain, 2.1 to 3.0; and short grain, <2.0 (Codex Alimentarius Commission, 1990).

Proposed tolerances for defects for milled rices are 0.5% each for organic and inorganic extraneous matter, 0.3% for rough rice, 1.0% each for brown rice and waxy rice, 2.0% for immature grains, 3.0% each for damaged and heat-damaged grains, 4.0% for red grains, 8.0% for redstreaked grains and 11.0% for chalky grains (Codex Alimentarius Commission, 1990). The proposed tolerances for milled parboiled rices are identical to those for milled rices except for no tolerance for chalky grains, 6.0% for heat-damaged grains and additional tolerances of 2.0% each for raw milled rice and pecks (grains with >25% of the surface coloured dark brown to black).

**2.2 RICE PRODUCTION**

**World rice production compared to other cereals**

The world annual cereal production for 1989 is shown in Table 1 . About 95% of the world's rice is produced in developing countries and 92% of it in Asia. In contrast only about 42% of the wheat produced is grown in developing countries. Production of rice, exports and imports and estimated irrigated areas of major rice producing countries are shown in Table 2. In 1988, China was the principal rice producer (35%) followed by India (22%), Indonesia (8.5%), Bangladesh (4.7%), Thailand (4.3%) and Viet Nam (3.4%). Of the major rice producers only Pakistan, the United States and Egypt had 100% irrigated rice land (IRRI, 1991 a). Non-irrigated rice cultivation predominates in many countries, such as Thailand and Brazil.

Among the cereals, rice production uses the highest proportion of land area. Of the 147.5 million ha of land devoted to rice production worldwide in 1989, developing countries contributed 141.4 million ha, or 96%. Asia accounted for 90% of the world's land area cultivated to rice; in this region, 132.1 million ha are used for this crop (FAO, 1990a).

Mean yields of cereal crops in various regions of the world in 1989 were lower in developing countries than in developed countries (FAO, 1990a), (Table 3). Rough rice yields were highest in Oceania, mainly Australia, followed by Europe and North and Central America, and were lowest in Africa and South America.

When the yields of the various cereals were adjusted using conversion factors based on extraction rates, rice was shown to have the highest food yield among the cereals. Food energy yields were approximately proportional to food yields, since energy contents of the cereals are similar. Food protein yield, however, was higher in white wheat flour than in milled rice because the protein content of wheat flour is higher than that of milled rice.

**TABLE 4 - Annual production of cereal crops, total tubers and roots and pulses by region, 1989 (million tonnes)**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Region** | **Wheat** | **Rough rice** | **Maize** | **Sorghum** | **Millet** | **Barley** | **Rye** | **Oats** | **Total cereals** | **Total tubers and roots** | **Soybean, peanut and pulses** |
| Africa | 12.7 | 10.7 | 37 | 13.7 | 9.3 | 5.6 | 0.01 | 0.2 | 90.5 | 102.6 | 11.7 |
| North and Central America | 84.2 | 9.5 | 212 | 22 | 0.2 | 20.9 | 1.2 | 9.1 | 360.6 | 23.8 | 59.9 |
| South America | 19 | 17.1 | 36.6 | 3.1 | 0.05 | 1.2 | 0.1 | 1.1 | 78.4 | 43.7 | 36.3 |
| Asia | 192 | 469.9 | 113.7 | 19.1 | 15.2 | 15.3 | 1.2 | 0.9 | 830 | 242 | 55.4 |
| Europe | 127.5 | 2.2 | 55.5 | 0.6 | 0.03 | 71.6 | 13.5 | 11.7 | 290.9 | 103 | 10.1 |
| Oceania | 14.3 | 0.8 | 0.3 | 1.2 | 0.02 | 4.4 | 0.02 | 1.7 | 23 | 2.9 | 1.8 |
| Soviet Union | 92.3 | 2.6 | 15.3 | 0.2 | 4.1 | 48.5 | 20.1 | 16.8 | 201.3 | 72 | 12.5 |
| World | 542 | 512.7 | 470.5 | 59.9 | 28.9 | 167.6 | 36.1 | 41.6 | 1 874.7 | 590.2 | 185.6 |
| Developed countries | 317.2 | 25.5 | 280.8 | 18.1 | 4.3 | 145.7 | 34.8 | 39.3 | 877.1 | 203.6 | 80.4 |
| Developing countries | 224.7 | 487.2 | 189.7 | 41.8 | 24.6 | 21.9 | 1.3 | 2.3 | 997.6 | 386.6 | 105.2 |

Source: FAO, 1990a, 1990b.

**TABLE 5 - Comparison of grain yield, food energy yield and protein yield of cereals based on energy and protein contents and conversion factor (extraction rate)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cereal** | **Mean yield (t/ha)** | **Conversion factor** | **Conversion factor derivation** | **Adjusted yield (t/ha)** | **Energy content (kcal/g)** | **Food energy yield (10-6 kcal/g)** | **Protein contenta (%)** | **Adjusted protein (%Nx6.25)** | **Food protein yield (t/ha)** |
| Wheat | 2.4 | 0.73 | white flour | 1.8 | 3.85 | 6.9 | 11.2 | 12.3 | 0.22 |
| Rough rice | 3.48 | 0.7 | milled rice | 2.4 | 3.75 | 9 | 7.5 | 7.9 | 0.19 |
| Maize | 3.66 | 0.56 | corn meal | 2 | 3.97 | 7.9 | 7.5 | 7.5 | 0.15 |
| Sorghum | 1.35 | 0.8 | white flour | 1.1 | 3.85 | 4.2 | 8.3 | 8.3 | 0.09 |
| Millet | 0.78 | 1 | whole grain | 0.78 | 3.94 | 3.1 | 5.6 | 5.6 | 0.04 |
| Barley | 2.31 | 0.55 | white flour | 1.3 | 3.9 | 5.1 | 8.2 | 8.2 | 0.11 |
| Rye | 2.14 | 0.83 | white flour | 1.8 | 3.75 | 6.8 | 7.3 | 8 | 0.14 |
| Oats | 1.79 | 0.58 | white oats | 1 | 3.92 | 3.9 | 14.2 | 14.2 | 0.14 |

a N factor was 6.25, except 5.7 for wheat and rye and 5.95 for rice.

Sources: FAO, 1990a; Lu & Chang, 1980; Eggum, 1969, 1977, 1979.

**HARVESTING AND CONSUMPTION**

**Harvesting**

Tropical rice is usually harvested at 20% or more moisture about 30 days after 50% flowering, when grains will provide optimum total and head rice yields. Moisture content at harvest is lower during the dry season than in the wet season because of sun-drying while the grains are in the intact plant. The actual period of dry-matter production is no more than 14 to 18 days, after which the grain undergoes drying.

Harvesting is carried out by cutting the stem, sun-drying and then threshing by hand by beating the rice heads on a slotted bamboo platform, by having animals or people tread on the crop or by the use of mechanical threshers. Combine harvesters are used in large areas such as the Muda estate in Malaysia and in the United States, Australia, Europe and Latin America.

Sun-drying to 14% moisture is a common practice but is unreliable during the wet season. Many mechanical dryers have been designed but have not been popular with farmers and processors. After drying, the rough rice is winnowed to remove the chaff using either a hand winnower or a manually operated wooden winnower.

**Rice consumption[[8]](#footnote-8)**

The dependence on rice for food energy is much higher in Asia than in other regions (FAO, 1984). The energy dependence on rice in South and Southeast Asia is higher than the energy dependence on any other staples in other regions. South Asia also has the lowest energy intake. Rice provides 35% to 59% of energy consumed for 2 700 million people in Asia (FAO, 1984). A mean of 8% of food energy is supplied by rice for 1000 million people in Africa and Latin America.

FAO statistics for 1987-89 showed that rice availability per caput could supply from 19% to over 76% of total food energy in different Asian countries. This range is equivalent to a milled rice availability ranging from 40 to 161 kg per caput annually.

The contribution of rice to protein in the diet, based on FAO Food, balance sheets for 1979-81, was 69.2% in South Asia and 51.4% in Southeast Asia (FAO, 1984). These percentages are higher than the contribution of any other cereal protein in any region of the world.

With the exception of the highest income countries in Asia, per caput rice consumption has remained stable or has increased moderately over the past 30 years. Total consumption continues to increase in close association with population and income growth. Rice supply, personal income and the availability and price of dietary substitutes are key determinants of the diversity in Asian diets, in addition to the quality of the rice being consumed. The greatest factor affecting demand, however, continues to be the unabated except China, which is 1984-86 average. Population growth, particularly in the poorest countries where in rice constitutes the most important component of the diet (Huang, 1987).

Within a country, rice consumption is higher in the rural than in the urban areas. While income elasticity for rice will undoubtedly decline as income increases, only Japan, Malaysia, Singapore, Taiwan and Thailand have income levels that support negative estimates of income elasticities for rice (Huang, David and Duff, 1991), (Table 9). However, the population and rice consumption of these five countries account for less than 10% of totals for Asia. In most Asian countries, therefore, rice is not an inferior food and income elasticities for rice will likely remain positive throughout the 1990s.

**Food availability and dietary intake**

Data on availability of food and nutrients are derived from FAO Food balance sheets and from nutrition surveys and studies on food consumption.

Food balance sheet data provide estimates of per caput food and nutrient availability taking into consideration food production, imports, exports, non-food uses, manufactured foods and wastage at the retail level.

Available data from nutrition surveys are often fragmentary and do not pertain to all countries. Even when data are available they may not always be representative and are often out of date.

There appears to be a large gap between availability of food and actual consumption, which indicates a significant influence of factors related to food access and utilization. However, these intake values strongly suggest the possibility of widespread prevalence of protein-energy malnutrition in young children. There is also enough indication from available consumption studies to suggest that special groups such as young children and pregnant mothers have dietary intakes that are low in energy, protein, vitamin A, iron, riboflavin and calcium.

**Nutritional problems in rice-consuming countries[[9]](#footnote-9)**

The nutritional situation in rice-consuming countries varies substantially depending on a web of interacting socio-economic, developmental, cultural, environmental and dietary factors. Regardless of the region, most rice-dependent economies have high population growth rates, low rice yields (except for China, Korea and Indonesia) and low gross national product (IRRI, 1989). Landholdings are small, low percentages of the population are economically active and literacy rates are variable in tropical Asia (Asian Development Bank, 1989).

Malnutrition is not just a problem of food availability; it is also a problem of income and food and income distribution (Flinn and Unnevehr, 1984). Because rice is a major source of income in rural Asia as well as a key component of private expenditure, increased productivity can reduce malnutrition both by increasing the incomes of the poorest rice producers and by increasing the availability of rice and the stability of rice prices.

A summary of nutritional problems prevalent in rice-consuming countries is presented. As 90% of the rice is produced and eaten by populations in Southeast Asia, the description is biased toward that region.

Among the major nutritional problems prevalent in rice-consuming countries, inadequate and unbalanced dietary intake is the most important one. In combination with other compounding factors, it leads to widespread prevalence of protein-energy malnutrition (PEM), nutritional anaemia (particularly from iron deficiency), vitamin A deficiency and iodine deficiency disorders (Chong, 1979; Scrimshaw, 1988; Khor, Tee and Kandiah, 1990). In addition, dietary deficiencies of thiamine, riboflavin, calcium, vitamin C and zinc are prevalent in many areas but often are not manifested in overt clinical syndromes.

These nutritional problems are not caused directly by the consumption of rice per se, but reflect an overall impact of multiple causative factors similar to those of other developing countries where rice is not a major staple.

**Gross nutrient composition**

Among the milling fractions of rice, the **bran has the highest energy and protein content and the hull has the lowest**. Only the brown rice fraction is edible. Abrasive or friction milling to remove the pericarp, seed-coat, testa, aleurone layer and embryo to yield milled rice results in loss of fat, protein, crude and neutral detergent fibre, ash, thiamine, riboflavin, niacin and a-tocopherol. Available carbohydrates, mainly starch, are higher in milled rice than in brown rice. The gradients for the various nutrients are not identical as evidenced from analysis of successive milling fractions of brown rice and milled rice (Barber, 1972), (Figure 4). Dietary fibre is highest in the bran layer (and the hull) and lowest in milled rice. Density and bulk density are lowest in the hull, followed by the bran, and highest in milled rice because of the low oil content. The nutritional properties of the rice grain are discussed further in Chapter 4.

The B vitamins are concentrated in the bran layers, as is a-tocopherol (vitamin E). The rice grain has no vitamin A, vitamin D or vitamin C (FAO, 1954). The locational gradient in the whole rice grain is steeper for thiamine than for riboflavin and niacin, resulting in a lower percent retention of thiamine (vitamin B1) in milled rice (Table 15). About 50% of the total thiamine is in the scutellum and 80 to 85% of the niacin is in the pericarp plus aleurone layer (Hinton and Shaw, 1954). The embryo accounts for more than 95% of total tocopherols (of which a-tocopherols account for one-third) and nearly one-third of the oil content of the rice grain (Gopala Krishna, Prabhakar and Sen, 1984). By calculation, 65% of the thiamine of brown rice is in the bran, 13% in the polish and 22% in the milled rice fraction (Juliano and Bechtel, 1985). Corresponding values for riboflavin are 39% in the bran, 8% in the polish and 53% in the milled rice fraction. Niacin distribution is 54% in the bran, 13% in the polish and 33% in the milled rice fraction.

The minerals (ash) are also concentrated in the outer layers of brown rice or in the bran fraction. A major proportion (90%) of the phosphorus in bran is phytin phosphorus. Potassium and magnesium are the principal salts of phytin. The ash distribution in brown rice is 51% in the bran, 10% in the germ, 10% in the polish and 28% in the milled rice fraction; iron, phosphorus and potassium show a similar distribution (Resurrección, Juliano and Tanaka, 1979). However, some minerals show a relatively more even distribution in the grain: milled rice retained 63% of the sodium, 74% of the calcium and 83% of the Kjeldahl N content of brown rice (Juliano, 1985b).

**TABLE 6 - Proximate composition of rough rice and its milling fractions at 14% moisture**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice fraction** | **Crude protein (g N x 5. 95)** | **Crude fat (g)** | **Crude fibre (g)** | **Crude ash (g)** | **Available carbohydrates (g)** | **Neutral detergent fibre (g)** | **Energy content** |  | **Density (g/ml)** | **Bulk density (g/ml)** |
|  |  |  |  |  |  |  | (kJ) | (hcal) |  |  |
| Rough rice | 5.8-7.7 | 1.5-2.3 | 7.2-10.4 | 2.9-5.2 | 64-73 | 16.4-19.2 | 1580 | 378 | 1.17-1.23 | 0.56-0.64 |
| Brown rice | 7.1-8.3 | 1.6-2.8 | 0.6-1.0 | 1.0-1.5 | 73-87 | 2.9-3.9 | 1520-1 610 | 363-385 | 1.31 | 0.68 |
| Milled rice | 6.3-7.1 | 0.3-0.5 | 0.2-0.5 | 0.3-0.8 | 77-89 | 0.7-2.3 | 1460-1 560 | 349-373 | 1.44-1.46 | 0.78-0.85 |
| Rice bran | 11.3-14.9 | 15.0-19.7 | 7.0-11.4 | 6.6-9.9 | 34-62 | 24-29 | 670-1 990 | 399-476 | 1.16-1.29 | 0.20-0.40 |
| Rice hull | 2.0-2.8 | 0.3-0.8 | 34.5-45.9 | 13.2-21.0 | 22-34 | 66-74 | 1110-1 390 | 265-332 | 0.67-0.74 | 0.10-0.16 |

Sources: Juliano, 1985b; Eggum. Juliano & Maniñgat, 1982; Pedersen & Eggum, 1983.

**TABLE 7 - Vitamin and mineral content of rough rice and its milling fractions at 14% moisture**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice fraction** | **Thiamine (mg)** | **Riboflavin (mg)** | **Niacin (mg)** | **a - Tocopherol (mg)** | **Calcium (mg)** | **Phosphorus (g)** | **Phytin P (g)** | **Iron (mg)** | **Zinc (mg)** |
| Rough rice | 0.26-0.33 | 0.06-0.11 | 2.9-5.6 | 0.90-2.00 | Oct-80 | 0.17-0.39 | 0.18-0.21 | 1.4-6.0 | 1.7-3.1 |
| Brown rice | 0.29-0.61 | 0.04-0.14 | 3.5-5.3 | 0.90-2.50 | Oct-50 | 0.17-0.43 | 0.13-0.27 | 0.2-5.2 | 0.6-2.8 |
| Milled rice | 0.02-0.11 | 0.02-0.06 | 1.3-2.4 | 75-0.30 | Oct-30 | 0.08-0.15 | 0.02-0.07 | 0.2-2.8 | 0.6-2.3 |
| Rice bran | 1.20-2.40 | 0.18-0.43 | 26.7-49.9 | 2.60-13.3 | 30-120 | 1.1-2.5 | 0.9-2.2 | 8.6-43.0 | 4.3-25.8 |
| Rice hull | 0.09-0.21 | 0.05-0.07 | 1.6-4.2 | 0 | 60-130 | 0.03-0.07 | 0 | 3.9-9.5 | 0.9-4.0 |

Sources: Juliano, 1985: Pedersen & Eggum, 1983.

**TABLE 8 - Amino acid content of rough rice and its milling fractions at 14% moisture (9 per 16 9 N)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice fraction** | **Histidine** | **Isoleucine** | **Leucine** | **Lysine + cysteine** | **Methionine + tyrosine** | **Phenylalanine** | **Threonine** | **Tryptophan** | **Valine** | **Amino acid scorea** |
| Rough rice | 1.5-2.8 | 3.0-4.8 | 6.9-8.8 | 3.2-4.7 | 4.5-6.2 | 9.3-10.8 | 3.0-4.5 | 1.2-2.0 | 4.6-7.0 | 55-81 |
| Brown rice | 2.3-2.5 | 3.4-4.4 | 7.9-8.5 | 3.7-4.1 | 4.4-4.6 | 8.6-9.3 | 3.7-3.8 | 1.2-1.4 | 4.8-6.3 | 64-71 |
| Milled rice | 2.2-2.6 | 3.5-4.6 | 8.0-8.2 | 3.2-4.0 | 4.3-5.0 | 9.3-10.4 | 3.5-3.7 | 1.2-1.7 | 4.7-6.5 | 55-69 |
| Rice bran | 2.7-3.3 | 2.7-4.1 | 6.9-7.6 | 4.8-5.4 | 4.2-4.8 | 7.7-8.0 | 3.8-4.2 | 0.6-1.2 | 4.9-6.0 | 83-93 |
| Rice hull | 1.6-2.0 | 3.2-4.0 | 8.0-8.2 | 3.8-5.4 | 3.5-3.7 | 6.6-7.3 | 4.2-5.0 | 0.6 | 5.5-7.5 | 66-93 |

a Based on 5.8 g lysine per 16 g N as 100% (V/HO, 1985).

Sources: Juliano, 1985b; Eggum. Juliano & Maniñgat, 1982; Pedersen & Eggum, 1983.

**Starch**

Starch is the major constituent of milled rice at about 90% of the dry matter. Starch is a polymer of D-glucose linked a -( 1-4) and usually consists of an essentially linear fraction, amylose, and a branched fraction, amylopectin. Branch points are a -(1-6) linkages. Innovative techniques have now shown rice amylose to have two to four chains with a number-average degree of polymerization (DPn) of 900 to glucose units and a ß-amylolysis limit of 73% to 87% (Hizukuri et al., 1989). It is a mixture of benched and linear molecules with DPn of 1100 to 1700 and 700 to 900, respectively. The branched fraction constitutes 25 to 50% by number and 30 to 60% by weight of amylose. The iodine affinity of rice amyloses is 20 to 21% by weight.

Rice amylopectins have ß-amylolysis limits of 56 to 59%, chain lengths of 19 to 22 glucose units, DPn of 5 000 to 15 000 glucose units and 220 to 700 chains per molecule (Hizukuri et al., 1989). The iodine affinity of rice amylopectin is 0.4 to 0.9% in low- and intermediate-amylose rices but 2 to 3% in high-amylose rices. Isoamylase-debranched amylopectins showed more longest chain fractions (DPn >100) (9 to 14%) in high-amylose samples with higher iodine affinity than in low- and intermediate-amylose samples (2 to 5%) and waxy rice amylopectin (0%), (Hizukuri et al., 1989).

Based on colorimetric starch-iodine colour absorption standards at 590 to 620 nm, milled rice is classified as waxy ( 1 to 2%), very low amylose (2 to 12%), low amylose (12 to 20%), intermediate (20 to 25%) and high (25 to 33%), (Juliano, 1979, 1985b). Recent collaborative studies showed that the maximum true amylose content is 20% and that additional iodine binding is due to the long linear chains in amylopectin (Takeda, Hizukuri and Juliano, 1987). Hence colorimetric amylose values are now termed "apparent amylose content".

The waxy endosperm is opaque and shows air spaces between the starch granules, which have a lower density than non-waxy granules. The structure of the starch granule is still not well understood, but crystallinity and staling are attributed to the amylopectin fraction.

**Protein**

Protein is determined by first carrying out micro Kjeldahl digestion and ammonia distillation and then using titration or colorimetric ammonia assay of the digest to determine nitrogen content, which is converted to protein by the factor 5.95. [The factor, based on a nitrogen content of 16.8% for the major protein of milled rice (glutelin), may be an overestimation; reappraisals have suggested values of 5.1 to 5.5 (5.17 + 0.25) (Mossé, Huet and Baudet, 1988; Mossé, 1990), 5.24 to 5.66 (mean 5.37) (Hegsted and Juliano, 1974) and 5.61 (Sosulski and Imafidon, 1990).]

Endosperm (milled rice) protein consists of several fractions comprising 15% albumin (water soluble) plus globulin (salt soluble), 5 to 8% prolamin (alcohol soluble) and the rest glutelin (alkali soluble), (Juliano, 1985b). Using sequential protein extraction, the mean ratio for 33 samples was found to be 9% prolamin, 7% albumin plus globulin and 84% glutelin (Huebner et al., 1990). The mean prolamin content of seven IRRI milled rices was 6.5% of their total protein (IRRI, l991b). The lysine content of rice protein is 3.5 to 4.0%, one of the highest among cereal proteins.

Rice bran proteins are richer in albumin than endosperm proteins and are found as distinct protein bodies containing globoids in the aleurone layer and the germ. These structures are different from endosperm protein bodies. Tanaka et al. ( 1973) reported the presence of 66% albumin, 7% globulin and 27% prolamin plus glutelin in aleurone protein bodies. Ogawa, Tanaka and Kasai (1977) reported the presence of 98% albumin in embryo protein bodies.

The endosperm protein is localized mainly in protein bodies (Figure 4). The crystalline (PB-II) protein bodies are rich in glutelin, and the large spherical protein bodies (PB-I) are rich in prolamin. Ogawa et al. (1987) estimated that endosperm storage proteins were composed of 60 to 65% PB-II proteins, 20 to 25% PB-I proteins and 10 to 15% albumin and globulin in the cytoplasm.

Rice starch granule amylose binds up to 0.7% protein that is mainly the waxy gene protein or granule-bound starchy synthase, with a molecular mass of about 60 kilodaltons (kd), (Villareal and Juliano, 1989b).

Rice glutelin consists of three acidic or a subunits of 30 to 39 kd and two basic or ß subunits of 19 to 25 kd (Kagawa, Hirano and Kikuchi, 1988). The two kinds of subunits are formed by cleavage of a 57-kd polypeptide precursor (Sugimoto, Tanaka and Kasai, 1986). Prolamin consists mainly (90%) of the 13- cd subunit plus two minor subunits of 10 and 16 kd (Hibino et al., 1989).

The essential amino acid contents of the glutelin and prolamin subunits (Table 17) showed lysine as limiting in these polypeptides except in the IEF3 fraction of the 13-kd prolamin subunit, which has 5.5% lysine and is limiting in methionine plus cysteine. Thus, glutelin has a better amino acid score than prolamin except for the 16-kd prolamin subunit. The 10-kd prolamin subunit has a high (6.8%) cysteine content.

**Lipid**

The lipid or fat content of rice is mainly in the bran fraction (20%, dry basis), specifically as lipid bodies or spherosomes in the aleurone layer and bran; however, about 1.5 to 1.7% is present in milled rice, mainly as non-starch lipids extracted by ether, chloroform-methanol and cold water-saturated butanol (Juliano and Goddard, 1986; Tanaka et al., 1978). Protein bodies, particularly the core, are rich in lipids (Choudhury and Juliano, 1980; Tanaka et al., 1978). The major fatty acids of these lipids are linoleic, oleic and palmitic acids (Hemavathy and Prabhaker, 1987; Taira, Nakagahra and Nagamine, 1988). Essential fatty acids in rice oil are about 29 to 42% linoleic acid and 0.8 to 1.0% linolenic acid (Jaiswal, 1983). The content of essential fatty acids may be increased with temperature during grain development, but at the expense of reduction in total oil content (Taira, Taira and Fujii, 1979).

**TABLE 9 - Aminogram (9/16 g N) of the acidic and basic subunits of rice glutelin and the mayor and minor subunits of prolamin**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Amino acid** | **Glutelin subunitsa** | | **Prolamin subunits** | | |
|  | 30-39 kd (acidic) | 19-25 kd (basic) | 13 kd | 10 kd | 16 kd |
| Histidine | 2.2-2.5 | 2.6-2.7 | 2.0-2.4 | 1.7 | 4.2 |
| Isoleucine | 3.2-3.3 | 4.1-4.9 | 3.8-5.4 | 1.6 | 3.6 |
| Leucine | 6.4-7.5 | 7.0-8.5 | 17.9-26.4 | 4.7 | 8.1 |
| Lysine | 2.2-3.0 | 3.0-4.1 | 0.4-5.5 | 1 | 3.3 |
| Methionine + cystineb | 0.2-1.9 | 0.1-2.4 | 0.7-1.2 | 22.5 | 5.3 |
| Phenylalanine + tyrosine | 10.0-10.5 | 10.1-10.8 | 12.7-21.6 | 4.3 | 7.6 |
| Threonine | 2.8-3.7 | 2.5-3.7 | 1.8-2.8 | 6.8 | 2.7 |
| Valine | 5.1-5.7 | 5.7-7.0 | 2.7-3.9 | 4.4 | 3.9 |
| Amino acid scorec(%) | 38-52 | 52-71 | 7-8d | 18 | 57 |

a: S-cyanoethyl glutelin subunits.

b: Only the IEF3 fraction of the 13-kd, 10-kd and 16-kd prolamin subunits had cystine. All glutelins had substituted cysteine residues

c: Based on 5.8% lysine as 100% (WHO, 1985).

d: AIternative value is 34% based on 2.5% methionine + cysteine as 100% (WHO, 1985).

Sources: Juliano & Boulter, 1976; Villareal & Juliano, 1978 (glutelin subunits); Hibino et al., 1989 (prolamin subunits).

Starch lipids are mainly monoacyl lipids (fatty acids and lysophosphatides) complexed with amylose (Choudhury and Juliano, 1980). The starch lipid content is lowest for waxy starch granules (<0.2%). It is highest for intermediatearnylose rices (1.0%) and may be slightly lower in high-amylose rice (Choudhury and Juliano, 1980; Juliano and Goddard, 1986). Waxy milled rice has more non-starch lipids than non-waxy rice. Starch lipids are protected from oxidative rancidity, and the amylose-lipid complex is digested by growing rats (Holm et al., 1983). However, starch lipids contribute little to the energy content of the rice grain. The major fatty acids of starch lipids are palmitic and linoleic acids, with lesser amounts of oleic acid (Choudhury and Juliano, 1980).

**TABLE 10 - Yield and composition of defatted and protease-amylase treated cell wall preparations obtained from different histological fractions of milling of brown rice**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice fraction** | **Yield (%deffated tissue)** | **Composition (% of total)** | | | | **Uronic acid in pectin (%)** | **Arabinose:xylose ratio** | |
|  |  | **Pectic substances** | **Hemicellulose** | ** - cellulose** | **Lignin** |  | **Pectic substances** | **Hemicellulose** |
| Caryopsis coat | 29 | 7 | 38 | 27 | 32 | 32 | 1.63 | 0.82 |
| Aleurone tissue | 20 | 11 | 42 | 16 | 25 | 25 | 1.78 | 0.84 |
| Germ | 12 | 23 | 47 | 9 | 16 | 16 | 2.29 | 0.96 |
| Endosperm | 0.3 | 27 | 49 | 1 | 34 | 34 | 1.09 | 0.64 |

Source: Shibuya, 1989.

**Non-starch polysaccharides**

Non-starch polysaccharides consist of water soluble polysaccharides and insoluble dietary fibre (Juliano, 1985b). They can complex with starch and may have a hypocholesterolaemic effect (Normand, Ory and Mod, 1981; Normand et al., 1984). The endosperm has a lower content of dietary fibre than the rest of brown rice (Shibuya, 1989), (Table 18). Reported values for neutral detergent fibre are 0.7% to 2.3% (Juliano, 1985b), (Table 14). In addition, the endosperm or milled rice cell wall has a low lignin content but a high content of pectic substances or pectin. Endosperm pectin has a higher uronic acid content but a lower arabinose-to-xylose ratio than the other grain tissues. The hemicellulose of endosperm also has a lower arabinose-toxylose ratio than the three other grain tissues.

**Volatiles**

The volatiles characteristic of cooked rice are ammonia, hydrogen sulphide and acetaldehyde (Obata and Tanaka, 1965). Upon cooking, all aromatic rices contain 2-acetyl-1-pyrroline as the major aromatic principle (Buttery et al., 1983). Volatiles characteristic of fat rancidity are aldehydes, particularly hexanal, and ketones.

**Consumers' criteria[[10]](#footnote-10)**

When more rice becomes available in the market, consumers' demand for superior quality rice is increased. Although sensory evaluations by laboratory panels and consumer panels give some indication on important criteria for rice quality, they do not reflect the properties for which consumers will actually pay a price premium in the retail market. By clearly identifying the quality characteristics valued by consumers, plant breeders can target attributes that are economically significant in breeding improvement research. The results could provide social scientists with an agenda for public policy research in rice marketing, technology assessment and research prioritization.

Rice grain quality denotes different properties to various groups in the postharvest system (Juliano and Duff, 1989). Although **variety is the principal factor contributing to grain quality**, good post-harvest handling can maintain or even improve it (Table 11). Moisture content is the most important quality criterion for rough rice. To the farmer, grain quality refers to quality of seed for planting material and dry grain for consumption, with minimum moisture, microbial deterioration and spoilage. The miller or trader looks for low moisture, variety integrity and high total and head milled rice yield. Market quality is mainly determined by physical properties and variety name, whereas cooking and eating quality is determined by physico-chemical properties, particularly apparent amylose content. In countries with marked variability in temperatures during the ripening periods, significant differences in grain quality have been reported within a variety. In tropical Asia, grain physico-chemical properties are relatively constant. Nutritional value is mainly determined by the milled rice protein content.

The major findings of research on the economics of grain quality from 1987 to 1989 by IRRI and national rice research programmes in Indonesia, Bangladesh, Malaysia, the Philippines and Thailand are that rice grain quality and quality preferences vary across countries and regions but some quality preferences are widely shared (IRRI and IDRC, 1992). Consumers in all the countries studied prefer higher head rice yield and more translucent grain. High-income consumers pay higher premiums for a larger number of quality characteristics than low-income consumers, reflecting their ability to pay. Preferences do not vary much across income levels, with one exception: **lower income consumers prefer rice that is more filling**. Laboratory analysis showed that Philippine rice labelled with a traditional variety name is usually a modern variety with shape or cooking characteristics similar to those of traditional varieties (Juliano et al., 1989b). Thus, the "traditional" label signals consumers that these rices have some desirable characteristics.

**TABLE 11 - Effects of environment, processing and variety on rice grain properties influencing quality at different steps of the post-harvest system**

|  |  |  |  |
| --- | --- | --- | --- |
| **Post-harvest process and associated grain property** | **Environment** | **Processing method** | **Variety** |
| **Harvesting** | +a | + | + (Growth duration, photoperiod, degree of ripening, dormancy) |
| **Threshing** | + | + | + (Threshability, shattering) |
| **Drying** | + | + | + (Crack resistance) |
| Yellowing | + | + | 0 |
| **Storage/ageing** | + | + | + (Waxy rice ages less than non-waxy) |
| **Parboiling** | + | + | + (Gelatinization temperature) |
| Pecky grain | + | + | + (Stink-bug resistance) |
| **Dehulling** | 0 | + | + (Hull tightness and content) |
| **Milling** |  |  |  |
| Head rice | + | + | + (Crack resistance) |
| **Marketing** |  |  |  |
| Size and shape | + | 0 | + (Genetically determined) |
| Degree of milling (whiteness) | + | + | + (Depth of grooves) |
| Head rice | + | + | + (Crack resistance) |
| Translucency | + | + | + |
| Aroma | + | + | + |
| Foreign matter | + | + | 0 |
| Shelf life | + | + | 0 |
| **Cooking and eating** |  |  |  |
| Amylose content | + | 0 | + (Volume expansion and texture) |
| Gelatinization temperature | + | 0 | + (Cooking time) |
| Gel consistency | + | 0 | + |
| Texture of cooked rice | + | + | + |
| Grain elongation | + | + | + |

a+, quality affected; O. no effect.

Source: Juliano & Duff, 1989.

Quality incentives appear to be transmitted from wholesale rice prices through to rough rice prices in Indonesia and the Philippines (IRRI and IDRC, 1992). However, this transmission is not perfect. The Philippine studies show that barriers to entry in milling influence pricing efficiency. The studies reveal the complexity of the transmission of information about quality from consumers to producers.

Given the importance of quality characteristics for creating and stimulating demand, especially among the higher-income urban sector, transmission of price and market signals and a greater degree of integration of the farm wholesale and retail market will be necessary to improve the farmgate price and to provide incentive to farmers to produce better-quality rice. Moreover, improvements in grain quality that do not lower yields will generally benefit all rice consumers by lowering the cost of better-quality rice (Unnevehr et al., 1985). If higher-quality varieties are widely adopted, producers will benefit by retaining better-quality rice for home consumption and by having a wider domestic market for their products. In addition, countries exporting rice would benefit from quality improvements that would expand their potential export market.

**NUTRITIONAL VALUE OF RICE AND RICE DIETS**

Rice is rich in energy and is a good source of protein, and it contains a reasonable amount of thiamine, riboflavin, niacin, vitamin E and other nutrients. It does not contain any vitamin C, D or A. Because of the quantity consumed it is the principal source of energy, protein, iron, calcium, thiamine, riboflavin and niacin in Asian diets.

Comparison of the nutrient content of staple cereals at 14% moisture and higher-moisture tuber foods (Tables 12 to 15) shows a somewhat higher energy content in cereals (Table 12), but a higher ascorbic acid content in tubers (Table 13). Because tubers contain more moisture they have lower nutrient and energy density than cereals. Cassava has an extremely low protein content (Table 12) even after correction for moisture differences.

The protein level of rice is similar to those of potato and yam on a dry weight basis but is the lowest among the cereals. Rice also has the lowest dietary fibre content.

Amino acid analysis (Table 14) showed lysine to be the first limiting essential amino acid in cereal proteins, but lysine content was highest in oats and rice among cereal proteins (Eggum, 1979), (Table 14). In contrast, tuber proteins are adequate in lysine but deficient in sulphur amino acids cysteine and methionine particularly at high protein levels (Eppendorfer, Eggum and Bille, 1979; Food and Nutrition Research Institute, 1980).

**TABLE 12 - Proximate composition of cereal and tuber staple foods (per 100 g)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Food** | **Moisture (%)** | **Protein (g Nx 6.25)** | **Crude fat (g)** | **Available carbohydrates (g)** | **Fibre (g)** | | | **Crude ash (g)** | **Energy (kJ)** | **Energy (kcal)** |
|  |  |  |  |  | **Dietary** | **Water insoluble** | **Lignin** |  |  |  |
| Brown rice | 14 | 7.3 | 2.2 | 71.1 | 4 | -2.7 | -0.1 | 1.4 | 1 610 | 384 |
| Wheat | 14 | 10.6 | 1.9 | 61.6 | 10.5 | -7.8 | -0.6 | 1.4 | 1 570 | 375 |
| Maize | 14 | 9.8 | 4.9 | 60.9 | 9 | -6.8 | 0 | 1.4 | 1 660 | 396 |
| Millet | 14 | 11.5 | 4.7 | 64.6 | 37 | -2.3 | 0 | 1.5 | 1 650 | 395 |
| Sorghum | 14 | 8.3 | 3.9 | 57.4 | 13.8 | -12.4 | -3 | 2.6 | 1 610 | 384 |
| Rye | 14 | 8.7 | 1.5 | 60.9 | 13.1 | -8.4 | (1 4) | 1.8 | 1 570 | 375 |
| Oats | 14 | 9.3 | 5.9 | 63 | 5.5 | -39 | 0 | 2.3 | 1 640 | 392 |
| Potato | 77.8 | 2 | 0.1 | 15.4 | 2.5 | -1.9 | 0 | 1 | 294 | 70 |
| Cassava | 63.1 | 1 | 0.2 | 31.9 | 2.9 | -2.2 | 0 | 0.7 | 559 | 133 |
| Yam | 71.2 | 2 | 0.1 | 22.4 | 3.3 | -2.6 | 0 | 1 | 411 | 98 |

Nitrogen-free extract by difference.

Sources: Souci, Fuchmann & Kraut, 1986; Eggum, 1969,1977,1979.

Whole-grain maize meal had protein quality comparable to that of wheat because of its large germ which is high in lysine-rich protein. Calculated amino acid scores based on the WHO/FAO/UNU pattern (WHO, 1985) showed tuber proteins to be superior to cereal proteins but do not take into consideration actual digestibility.

Rice has the highest protein digestibility among the staples (Table 15). Potato protein had a higher biological value than cereal proteins, consistent with its high amino acid score, but its net protein utilization (NPU) was lower than that of rice. Utilizable protein was comparable in brown rice, wheat, maize, rye, oats and potato but was lower in sorghum and higher in millet. Rice has the highest energy digestibility, probably in part because of its low dietary fibre and tannin content (Tables 12 and 14).

Cereal proteins are less digestible by children and adults than egg and milk protein, except for wheat endosperm (WHO, 1985), (Table 16). Digestibility values for cooked milled rice proteins were lower than those for raw milled rice (almost 100%) when tested on growing rats but were close to the values for other cereal proteins, except for the low value for sorghum. Based on the mean true digestibility of egg, milk, cheese, meat and fish protein of 95%, the relative digestibility of milled rice is 93% (WHO, 1985). The protein of cooked rice has a lower true digestibility in humans than the protein of raw rice in growing rats (Table 16). Cooked rice protein also has a true digestibility of 89% in growing rats (Eggum, Resurreción and Juliano, 1977).

**TABLE 13 - Vitamin and mineral content of cereal and tuber staple foods (per 100 g)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Food** | **Carotene (mg)** | **Thiamine (mg)** | **Riboflavin (mg)** | **Niacin (mg)** | **Ascorbic acid (mg)** | **Vitamin E (mg)** | **Iron (mg%)** | **Zinca (mg%)** |
| Brown rice | 0 | 0.29 | 0.04 | 4 | 0 | 0.8 | 3 | 2 |
| Wheat | 0.02 | 0.45 | 0.1 | 3.7 | 0 | 1.4 | 4 | 3 |
| Maize | 0.37 | 0.32 | 0.1 | 1.9 | 0 | 1.9 | 3 | 3 |
| Millet | 0 | 0.63 | 0.33 | 2 | 0 | 0.07 | 7 | 3 |
| Sorghum | 10 | 0.33 | 0.13 | 3.4 | 0 | 0.17 | 9 | 2 |
| Rye | 0 | 0.66 | 0.25 | 1.3 | 0 | 1.9 | 9 | 3 |
| Oats | 0 | 0.6 | 0.14 | 1.3 | 0 | 0.84 | 4 | 3 |
| Potato | 0.01 | 0.11 | 0.05 | 1.2 | 17 | 0.06 | 0.8 | 0.3 |
| Cassava | 0.03 | 0.06 | 0.03 | 0.6 | 30 | 0 | 1.2 | 0.5 |
| Yam | 0.01 | 0.09 | 0.03 | 0.6 | 10 | 0 | 0.9 | 0.7 |

a Zinc level of cassava and yam from Bradbury & Holloway (1988).

Sources: Souci, Fuchmann & Kraut, 1986: Eggum, 1969,1977, 1979.

Nitrogen balance studies in Peruvian preschool children fed cooked cereals (Graham et al., 1980; MacLean et al., 1978, 1979, 1981) and potato (Lopez de Romaña et al., 1980) showed the highest apparent N absorption for wheat noodles but the highest apparent N retention for peeled potato and the highest protein quality, based on apparent N retention of casein control diets, for potato and milled rice (Table 17). Utilizable protein is highest for wheat and rice. High-lysine or opaque-2 maize is inferior to milled rice in protein quality but better than normal maize. Energy digestibility, indexed by faecal dry weight, was lowest for sorghum, probably because of its high tannin content (see Table 14).

**TABLE 14 - Amino acid and tannin content in whole-grain cereals and tubers**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Food** | **Lysine** | **Threonine** | **Methionine + cystine** | **Tryptophan (g/16 g N)** | **Amino acid scorea(%)** | **Tannin(%)** |
| **(g/16 g N)** | **(g/16 g N)** | **(g/16 g N)** |
| Brown rice | 3.8 | 3.6 | 3.9 | 1.1 | 66 | 0.4 |
| Wheat | 2.3 | 2.8 | 3.6 | 1 | 40 | 0.4 |
| Maize | 2.5 | 3.2 | 3.9 | 0.6 | 43 | 0.4 |
| Millet | 2.7 | 3.2 | 3.6 | 1.3 | 47 | 0.6 |
| Sorghum | 2.7 | 3.3 | 2.8 | 1 | 47 | 1.6 |
| Rye | 3.7 | 3.3 | 3.7 | 1 | 64 | 0.6 |
| Oats | 4 | 3.6 | 4.8 | 0.9 | 69 | 1.1 |
| Potato | 6.3 | 4.1 | 3.6 | 1.7 | 100 |  |
| Cassava | 6.3 | 3.4 | 2.6 | 1 | 91 |  |
| Yam | 6 | 3.4 | 2.9 | 1.3 | 100 |  |

aAll based on 5.8% lysine as 100%, except based on 1.1% tryptophan as 100% for cassava (WHO, 1985).

Sources: Eggum, 1969, 1977, 1979; Food and Nutrition Research Institute, 1980.

**TABLE 15 - Balance data of whole-grain cereals and potato in five rats**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Food** | **True N** | **Biological** | **Net protein** | **Utilizable** | **Digestible energy** | |
| **digestibility** | **value** | **utilization** | **protein** |
| **(%)** | **(%)** | **(%)** | **(%)** |
|  |  |  |  |  | **(kcal/g)** | **(% of total)** |
| Brown rice | 99.7 | 74 | 73.8 | 5.4 | 3.7 | 96.3 |
| Wheat | 96 | 55 | 53 | 5.6 | 3.24 | 86.4 |
| Maize | 95 | 610 | 58 | 5.7 | 3.21 | 81 |
| Millet | 92 | 60 | 56 | 6.4 | 3.44 | 87.2 |
| Sorghum | 84.8 | 59.2 | 50 | 4.2 | 3.07 | 79.9 |
| Rye | 77 | 77.7 | 59 | 5.1 | 3.18 | 85 |
| Oats | 84.1 | 70.4 | 59.1 | 5.5 | 2.77 | 70.6 |
| Potato | 82.7 | 80.9 | 66.9 | 5.2 | - | - |

Sources: Eggum, 1969, 1977, 1979.

**TABLE 16 - Calculated true digestibility by adults and children of various cereal proteins as compared to egg, milk and meat protein**

|  |  |  |
| --- | --- | --- |
| **Protein source** | **Mean** | **Digestibility relative to reference proteins** |
| Rice, milled | 88 ± 4 | 93 |
| Wheat, whole | 86 ± 5 | 90 |
| Wheat endosperm (farina) | 96 ± 4 | 101 |
| Maize, whole | 85 ± 6 | 89 |
| Millet | 79 | 83 |
| Sorghum | 74 | 78 |
| Oatmeal | 86 ± 7 | 90 |
| Egg | 97 ± 3 | 100a |
| Milk | 95 ± 3 |  |
| Meat, fish | 94 ± 3 |  |

a Mean true digestibility of 95%.

Sources: Hopkins, 1981; WHO, 1985.

**Environmental influence on rice composition**

Environmental factors are known to affect the composition of the rice grain (Juliano, 1985b). Protein content tends to increase with wider spacing or in borders and in response to high N fertilizer application, especially at flowering. Short growth duration and cloudy weather during grain development, as occurs in the wet season, may increase protein content. Stresses such as drought, salinity, alkalinity, high or low temperature, diseases or pests may increase the protein content of the rice grain. An increase in protein content is essentially at the expense of a reduction in starch content.

Environmental factors that increase protein content, such as soil type, ambient temperature during ripening and growth duration, also increase the ash content of brown rice but have no effect on its fat content. Mineral nutrition affects the protein content of the rice grain: soil organic matter, total nitrogen, exchangeable calcium, available copper and molybdenum and total chlorine all tend to increase the grain protein content (Huang, 1990).

As growth duration increases, brown rice protein content decreases (IRRI, 1988b). By contrast, yield and brown rice protein were not always significantly negatively correlated.

Upland culture had a variable effect on the protein content of eight varieties of rice grown in Côte d'Ivoire; five showed a lower milled rice protein content and two showed a higher protein content under upland culture (Villareal, Juliano and Sauphanor, 1990).

In Punjab, Pakistan, high soil salinity increased the brown rice protein content in three of four varieties differing in salinity tolerance but had no effect on the protein content of the fourth (Siscar-Lee et al., 1990). Soil sulphur deficiency reduces grain yield without having any adverse effect on the cysteine and methionine contents of the rice protein (Juliano et al., 1987).

The mineral content of the grain is affected by the mineral content of the soil and of the irrigation water. For instance, pollution of irrigation water with mine tailings has resulted in high cadmium content in some Japanese rices which has proved to be harmful (Kitagishi and Yamane, 1981).

**RICE POST-HARVEST PROCESSING, PARBOILING AND HOME PREPARATION[[11]](#footnote-11)**

**Harvesting**

Harvesting includes numerous operations, including: cutting the rice stalk; reaping the panicles; laying out the paddy-on-stalk or stacking it to dry; and bundling for transport. Correct harvesting and handling operations can considerably reduce post-production losses. Excessive handling creates problems in terms of both quality and quantity.

The sequence of manual harvesting, field drying, bundling and stacking in traditional systems can cause losses of between 2% and 7% (Toquero and Duff, 1974). At this stage, losses can occur when secondary tiller panicles are missed when the sickle cuts 60 cm above ground in lowland rice. Also, delayed harvest causes shattering losses during harvesting and transport.

**Harvesting methods**

There are a variety of different methods for rice harvesting, with traditional manual methods prevailing in developing countries:

*Panicle reaping*

This is accomplished by using a hand-held cutting tool (Yatab in the Philippines, Ani-ani in Indonesia, Kae in Thailand, Espigadora in Bolivia). The method is used in areas where traditional varieties are resistant to shattering. Resistance to shattering is particularly important during handling and when transporting the bundles of panicles from field to house. The labour time required for this method is 240 labour-hours/ha (done mostly by women and older children), which is four times that required with the hand-sickle method. It remains popular because of the social custom of chatting while working. In addition, it generates income among the landless rural population and is suitable for hilly and terraced areas.

*Long stalk cutting by sickle*

This is a widely used manual method presenting different styles in the design. It requires between 80 and 180 labour-hours/ha. The stalk is cut about 10 to 15 cm above the ground or with a stalk length of about 60 to 70 cm for easy bundling and threshing. Reaping efficiency depends on various cultural practices, plant density and variety, degree of lodging, soil conditions and the skill of the harvester. Lodged paddy and saturated soils may considerably reduce the cutting rate.

*Modern mechanical methods*

These methods are generally used when labour is scarce; otherwise, harvesting is generally still done with a sickle in most developing countries. The use of mechanized harvesting methods in some areas depends upon the custom and suitability of the machine and other socio-economic factors. Some examples of these machines are:

Reaper binder: once very popular, it is currently being replaced by the combine. The machine cuts and bundles stems together and lays them in the field in a single operation.

Combine: very popular, its adoption in Japan, Korea and other Asian countries is slow only because of its high cost. The binder can harvest 0.05 ha/hour. A similar, large model was developed in Thailand to resolve the problems of scarcity and cost of labour; Viet Nam may also adopt mechanized methods because of economies of scale. Some other Asian countries import second-hand, large combines for harvesting the basic rice crop. In commercial rice production, large combines are generally used in countries such as Brazil and Uruguay in Latin America, in Europe and in the United States of America. In Africa, on the other hand, these machines (introduced through international aid programmes) have had little impact because of the lack of maintenance facilities.

Stripper harvester: an innovation from IRRI and an adaptation of the rotary stripping combine principle developed by Silsoe Research Institute in the United Kingdom, it works with varieties which are non-lodging, medium height, with erect panicles and low to medium shattering (Naphire, 1997).

There continue to be constraints for farmers in developing countries to the adoption of mechanical harvesting methods: low income, reluctance to move away from traditional methods, poor mechanical aptitude, the desire to save straw for off-farm uses, lack of access to the field, excessive moisture content, uneven ripening etc. Other limiting factors are the high cost of imported equipment and the fact that machinery management must be competitive with the relatively low cost of labour (IRRI, 1997).

**Threshing**

During threshing the paddy kernel is detached from the panicle, an operation which can be carried out either by “rubbing”, “impact” or “stripping”. Rubbing may be done with trampling by humans, animals, trucks or tractor; however, the grain becomes damaged. Mechanical threshers adopt mainly the impact principle, but there is also a built-in stripping action.

With a paddy thresher, the unthreshed paddy may be either held or thrown in. In the “hold-on” type, the paddy is held still in the cylinder while spikes or wire loops perform impact threshing. In a “throw-in” machine, whole paddy stalks are fed into the machine and a major portion of the grain is threshed by the initial impact caused by bars or spikes on the cylinder.

In a conventional threshing cylinder, stripping may also be used for paddy threshing; impulsive stripping normally occurs with impact threshing. In a throw-in thresher, large amounts of straw pass through the machine and some designs use straw walkers to initially separate the loose grain from the bulk of the straw and chaff (Lantin, 1997).

IRRI developed the Votex Ricefan thresher. A portable machine, as well as being suitable for both paddy panicles and paddy stalks, it may be adapted for wheat, corn, soybean and beans. The Votex Ricefan thresher has been widely accepted among Bolivian paddy farmers (Terán, 1996) and may be either manually or power-operated.

Manual threshing is pedal-operated and involves: treading; beating the panicles on a tub, threshing board or rack; or beating the panicles with a stick or flail device. The thresher consists of a rotating drum with wire loops which strip the grain from the panicle when the paddy is fed by hand. This equipment is portable, can be used in hilly areas and is easily operated by women.

In power threshing, the harvested crop is trampled by tractor or truck tyres in developing countries. The grain is separated from the straw by hand and then cleaned by winnowing.

Losses may occur during threshing for various reasons:

* In manual threshing by beating, some grains remain in the bundle panicles and a repeat threshing is required.
* Grain is scattered when the bundles are lifted just before threshing.
* Grain can stick in the mud floor.

Birds and domestic fowls feed on the grain (Lantin, 1997).

**Drying**

Paddy as a living biological material absorbs and gives off moisture depending on: paddy moisture content, relative humidity of the air and temperature of the surrounding atmosphere. The respiration of the paddy is manifested in various ways: decrease in dry matter weight; utilization of oxygen; evolution of carbon dioxide; and the release of energy in the form of heat. However, respiration is negligible when the moisture content is between 12 and 14%.

By and large, paddy is harvested with moisture content of 24 to 26% (higher in the rainy season and lower in the dry season). It has a high respiration rate and is susceptible to attacks by micro-organisms, insects and other pests. The heat released during the respiration process is retained in the grain and in the bulk due to the insulating effect of the rice husk, resulting in losses in terms of both quantity and quality. Therefore, harvested grain with high moisture content must be dried within 24 hours: to 14% for safe storage and milling, or at most 18% for temporary storage of 2 weeks when it is not possible to dry any faster. Delayed drying may result in non-enzymatic browning (stack-burning), microbial growth and mycotoxin production in parboiled rice (NRI, 1991).

Square areas (10 x 10 m) of concrete have been successfully used for sun-drying in rural communities of rice farmers in Bolivia (Terán, 1996). Small rural farmers in these regions also use tarpaulins for paddy sun-drying. The main constraint of sun-drying is the dependence on good weather conditions, which can become a serious problem, particularly in tropical rainy countries.

Losses due to bad drying practices range from 1 to 5% and it is mainly the quality which is affected. Good drying is crucial for minimizing post-harvest losses, since it directly affects safe storage, transportation, distribution and processing quality.

A temperature of 43°C is recommended for drying paddy for seeds and this can be achieved with shade drying. Higher temperatures can lead to physicochemical disorders in the grain (Zheng et al., 2000). The cheapest drying method is sun- or solar drying, practised by farmers, cooperatives, commercial millers and government grain agencies in most developing countries. Between 70 and 90% of the field harvest retained in the farm is sun-dried, with the work generally performed by women and children. Drying usually takes place on paved areas next to the warehouse and rice mills; the paved areas slope slightly so that water can drain away during the rainy season.

Early harvesting when moisture content is high helps minimize shattering losses in the field. In crops of high-yielding varieties it is necessary to dry large quantities of wet grain in the shortest time so as to minimize rice spoilage. An artificial or mechanical dryer speeds up the drying process, reduces handling losses, maintains grain quality and gives better control during drying.

The temperature for drying paddy should not be higher than 54.4°C for food grain using the dry batch system. Low temperatures help preserve the rice aroma principle 2-acetyl-1-pyrroline (Itani and Fushimi, 1996).

The choice of a drier system depends on several factors: drying capacity requirement, ease of installation and operation, portability, full heat source and the initial cost of purchase. A wide range of drying equipment and methods are available for rough rice, and computer models have been developed to assist agricultural research workers or farmers in their selection of dryers for a given crop and situation (Dissanayake, 1991).

The adoption of an artificial drying system by rice farmers has numerous constraints:

* High fuel costs.
* Small farmers producing a small volume of paddy can easily use sun-drying.
* It is popular belief that the bleaching effect of sun-dried paddy results in whiter grains than artificially dried paddy.
* Lack of capital for investing in artificial dryers.
* Lack of know-how about the drying technology (Andales, 1996).

The main causes of losses during drying are as follows:

* Grains shattering from stalks or spilling out from bags during transport.
* Birds and domestic fowls.
* Spill-out outside the drying area.
* Over-drying, especially during sun-drying.
* Delayed drying or no grain aeration, resulting in stack-burning.

**Paddy cleaning**

This is an important operation and highly recommended not only on a large and medium commercial scale, but also on a small scale. It consists of the separation of undesirable material, such as weed seeds, straw, chaff, panicle stems, empty grains, inmate and damaged grains, sand, rocks, stone, dust, plastic and even metal and glass particles. The degree of cleanness of the paddy reflects to some extent the care applied during harvesting, threshing and handling.

In developing countries, farmers clean the paddy straight after manual threshing. First, they use hand-raking and sifting to remove straw, chaff and other large and dense materials, then winnowing, i.e. making the grain fall down to be collected on a surface such as tarpaulin or a nylon sheet. The method depends on air natural conditions and is very slow.

A hand- or pedal-operated blower may be used with a cleaning capacity of 250 kg/hour. Alternatively, an engine-powered fan is used and can simultaneously perform both operations: grading and cleaning. The latter is expensive but has the advantages of being faster and requiring less labour (particularly women’s labour).

A versatile model from IRRI, known as “GC-7” and with a capacity of 1 t/hour for paddy and 3 t/hour for maize, was widely accepted by Bolivian farmers (CIAT, 1996). The main advantage of this model is that it can be manufactured in developing countries in local metal workshops.

Cleaned paddy demands a higher price than non-cleaned paddy - an incentive for cleaning the paddy. In contrast, lack of cleaning often results in a higher concentration of contaminants in the milled rice. Another consideration is that stones and other hard particles shorten the life of the milling equipment. Finally, milling recovery is low when paddy is not cleaned (Lantin, 1997).

**Storage**

Paddy may be produced once a year or throughout the year. Productivity has increased due mainly to the use of HYVs in irrigated areas. Consequently, it is important to improve and expand the post-harvest infrastructure for better handling, processing and storage of the paddy. Storage is a critical operation and losses can easily occur if preventive measures are not taken.

In Asia, between 70 and 90% of farm-produced paddy remains in the farms and the rest is deposited in or sold to agricultural cooperatives or sold to the private sector. Appropriate storage is therefore required, both for rice for consumption (milled or paddy) and for rice for seed purposes. The storage structure must protect the paddy from: extreme heat or cold; moisture, which causes microbial and fungal growth; and insect pests and rodents which consume or damage the rice. In Bolivia, small metallic silos with a capacity of 115 kg have been successfully used by small rice farmers (CIAT, 1996).

At farm household level, storage is essential for food security or as a commodity bank for conversion into cash when required. Unfortunately, small-scale or marginal farmers often lack the resources to store large amounts of grain and do not have a large storage structure; they therefore are obliged to sell their paddy to traders or buyers immediately after harvest. They carry out no further processing (drying, cleaning and grading) because of the immediate need for cash, and there is a lack of incentive to dry, as there is no significant difference in price between wet and dried paddy. The paddy is only dried for safe storage, and then only the amount necessary for consumption or a little more for cash conversion or to sell at a better price.

The traditional storage structure used by farmers in Asia is a container made of woven bamboo, palm leaves or wood. Problems occurring include: spoilage due to high grain moisture, rain, storms or flooding; dirt contamination; losses due to insects, rodents and even theft; collapse of the structure (Lantin, 1997).

The main causes of losses during storage are:

* Attack by insects, rodents and birds as a result of inadequate protection.
* Long-term storage with 14% or higher moisture content, or more than 2 weeks’ storage with 18% moisture.
* Theft and pilferage in the warehouse.

The paddy retained for storage is sun-dried several times and cleaned before loading into the storage container. The farmer determines the dryness required for storage on the basis of experience. Dryness is measured by pressing a bunch of grains hard into the hand or biting several grains: a fully dried grain is hard. Paddy is usually stored with a moisture content of 14% or less. Paddy is normally stored in a 1-tonne-capacity container for 6 to 12 months. Losses in farm storage have been estimated at about 6.2% (Ren-Yong et al., 1990).

**Milling**

Paddy or the rice grain consist of the hull or husk (18-28%) and the caryopsis or brown rice (72-82%). Brown rice consists of: an outer layer (pericarp, tegmen and aleurone layers) called bran (6-7%); the germen or embryo (2-3%); and the edible portion (endosperm 89-94%) (Chen et al., 1998). The rice milling operation is the separation of the husk (dehusking) and the bran (polishing) to produce the edible portion (endosperm) for consumption. Although a theoretical mill recovery would be between 71 and 73%, in practical terms it is possible to obtain between 68 and 70% from a good variety of paddy. Milling losses can be reduced by adopting small-scale modern rubber roll sheller and introducing parboiling of paddy before milling. Table 2 shows the advantages and disadvantages of parboiled rice.

**TABLE 17 - Some advantages and disadvantages of parboiled rice**

|  |  |
| --- | --- |
| **Advantages** | **Disadvantages** |
| Milling or dehusking is easier and costs less | Bran removal is more difficult and costs more |
| Milled rice has fewer brokens and is nutritious | Cannot be used in starch-making or brewing |
| Increased head and total rice out-turn | Doubles the total processing cost |
| Rice is more resistant to storage insect pests | Rice easily becomes rancid |
| Bran contains more oil | Requires large capital investment |
| Less starch lost in cooking and keeps longer |  |

Source: Lantin, 1997 (adapted)

**Parboiling**

The traditional parboiling process involves soaking rough rice overnight or longer in water at ambient temperature, followed by boiling or steaming the steeped rice at 100°C to gelatinize the starch, while the grain expands until the hull's lemma and palea start to separate (Gariboldi, 1984; Bhattacharya, 1985; Pillaiyar, 1988). The parboiled rice is then cooled and sun-dried before storage or milling.

Modern methods involve the use of a hot-water soak at 60°C (below the starch gelatinization temperature) for a few hours to reduce the incidence of aflatoxin contamination during the soaking step. Leaching of nutrients during soaking aggravates the contamination, with the practice of recycling the soak water. Soaking sound, rough rice in water inoculated with Aspergillus parasiticus did not result in aflatoxin contamination of parboiled rice (Yap et al., 1987), suggesting that contamination probably has to be present in the grain prior to soaking (Bandara, 1985).

Vacuum infiltration to de-aerate the grain prior to pressure soaking is applied to obtain a good-quality product, as is pressure parboiling. The parboiled product has a cream to yellow colour depending on the intensity of heat treatment. Aged rice may give a grayish parboiled rice, probably because it has a lower pH owing to the presence of free fatty acids.

Parboiling gelatinizes the starch granules and hardens the endosperm, making it translucent. Chalky grains and those with chalky back, belly or core become completely translucent on parboiling; a white core or centre indicates incomplete parboiling of the grain.

Heated-sand drying results in parboiling of the higher-moisture wetseason crop but not of the dry-season crop. Parboiling results in inward diffusion of water-soluble vitamins, in addition to partial degradation of thiamine during heat treatment, except in heated-sand drying (Padua and Juliano, 1974), (Table 39). Riboflavin content is not decreased by parboiling (Grewal and Sangha, 1990). Despite the degradation of thiamine, parboiled milled rice had a higher vitamin content than raw milled rices in all parboiling procedures tested (Padua and Juliano, 1974).

**TABLE 18 - Effect of parboiling method on thiamine content and protein**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Number  of Samples** | **Degree of milling (%)** | | **Thiamine (µg/g)** | | | | **Protein (%)** | |
|  |  | **Raw** | **Treated** | **Raw brown** | **Treated brown** | **Raw milled** | **Treated milled** | **Raw milled** | **Treated milled** |
| Modified traditional(hot soak) | 2 | 11 | 10.6 | 3.2 | 2.5 | 0.4 | 1.9 | 8.3 | 7.3 |
| Lab. Method(hot soak) 121°C 10 min | 2 | 11.6 | 12 | 3.8 | 3.2 | 0.6 | 2.9 | 9 | 8.6 |
| US commercial parboiling | 3 | 12.2 | 12.6 | 3.9 | 2.8 | 0.5 | 2.1 | 6.6 | 6.2 |
| Heated-sand drying | 2 | 10.5 | 10.2 | 3.7 | 3.6 | 0.6 | 1.8 | 8.2 | 7.8 |
| LSD (%) |  | 0.8 |  |  | 0.3 |  | 0.5 |  | 0.9 |

Source: Padua & Juliano, 1974.

Earlier results demonstrated that the water-soluble B vitamins, thiamine, riboflavin and niacin, are higher in milled parboiled rice than in milled raw rice (Kik and Williams, 1945). Oil and protein are reported to diffuse outward during parboiling, based on microscopic observations; they cannot diffuse as readily through cell walls as water-soluble vitamins, but the spherosome structure is destroyed. At similar degrees of milling, parboiled milled rice has lower protein content than raw milled rice (Table 39), but parboiled rice bran has more protein and oil than raw rice bran (Padua and Juliano, 1974). The composition of the milling fractions can be explained by a lower endosperm contamination of the bran in parboiled rice.

Parboiling results in some yellowing of the grain depending on the severity of the heat treatment. In addition, black spots diffuse to form dark brown to black regions or pecks, wherein at least 25% of the grain surface is coloured. Although parboiled grains are harder than raw rice, they are also susceptible to fissuring during drying, particularly below 18% moisture when free water becomes scarce in the grain.

**TABLE 19 - Nutritional properties of two milled rices, raw and parboiled[[12]](#footnote-12)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Rice type** | **Crude protein** | **Lysine** | **Balance data in five growing rats** | | | |
|  | **(%NX6.25)** | **(g/16 8 N)** |
|  |  |  | **True digestibility** | **Biological value** | **Net protein utilization** | **Digestible Energy** |
| **(% of N intake)** | **(% of digested N)** | **(% of N intake)** | **(% of intake)** |
| **IR480-5-9b** | 11.2 | 3.4 | 100.4 | 66.8 | 67.1 | 97 |
| Raw |
| Parboiled 10 min | 10.4 | 3.6 | 94.7 | 70.4 | 66.7 |  |
| **IR8 c** | 7.7 | 3.6 | 96.2 | 73.1 | 70.3 | 96.6 |
| Rawd |
| Parboiled 20 min | 7.2 | 3.7 | 89.7 | 78.1 | 70 | 95.2 |
| Parboiled 60 min | 7.4 | 3.5 | 88.6 | 79.5 | 70.4 | 94.7 |
| LSD (5%)b | 0.2 | 0.2 | 0.9 | 1.1 | 1.4 | 0.5 |

a Parboiling done at 121°C, properties at 14% moisture content,

b Eggum, Resumcci6n & Juliano, 1977.

c Eggum et al., 1984.

d Eggum & Juliano, 1973; Eggum, Alabata & Juliano, 1981.

Freshly parboiled rice may be milled directly with little breakage since the grains are pliable at high moisture content. Because of the damage to the spherosome structure, the bran of parboiled rice tends to agglomerate during milling and clog the sieves. In addition, greater milling pressure is required for parboiled rice because of the hardened endosperm.

Although parboiled rice is claimed to have a better shelf-life than raw rice because of the gelatinized starchy endosperm, its slightly open hull also makes it more exposed to insect attack. In addition, Asian parboiled rice is known to have aflatoxin contamination which is rarely found in raw rice (Tulpule, Nagarajan and Bhat, 1982; Vasanthi and Bhat, 1990). However, most of the aflatoxin is removed by processing.

The pressure parboiling process decreases the true digestibility of rice protein in growing rats (Eggum, Resurrección and Juliano, 1977; Eggum et al., 1984), (Table 18). However, there is a compensatory increase in biological value such that net protein utilization is comparable in raw and parboiled milled rice. Prolonging the pressure parboiling from 20 to 60 minutes did not further reduce the protein digestibility of IR8 rice.

Parboiling also removes cooked rice volatiles including free fatty acids, inactivates enzymes such as lipase and lipoxygenase, kills the embryo and decomposes some antioxidants (Sowbhagya and Bhattacharya, 1976). Hence, cooked parboiled rice lacks the volatiles characteristic of freshly cooked raw rice hydrogen sulphide, acetaldehyde and ammonia (Obata and Tanaka, 1965). The volatiles identified were mainly aldehydes and ketones (Tsugita, 1986).

Parboiled rice takes longer to cook than raw rice and may be presoaked in water to reduce the cooking time to be comparable to that of raw rice. The cooked grains are less sticky, do not clump end are resistant to disintegration; the grains are also harder. They also tend to expand more in girth rather than in length as compared to raw rice.

Most of the varieties parboiled in Bangladesh, Sri Lanka, India and Pakistan are the high-amylose rices that are common in these regions. In Thailand, both intermediate- and high-amylose rices are parboiled for export. Mainly long-grain, intermediate-amylose rice is parboiled in the United States, and intermediate- to low-amylose coarse japonica rices are parboiled in Italy.

Roasting of steeped rice grain at 250°C for 40 to 60 seconds also results in parboiling, but the product has a softer texture because the starch is immediately dried without permitting recrystallization or retrogradation of the starch gel, mainly the amylose fraction. The roasted grain is flattened or flaked with a wooden mortar and pestle, a roller flaker or an edge runner (Shankara et al., 1984) and then winnowed to remove hull and germ.

**Processing[[13]](#footnote-13)**

Milling is a crucial step in post-production of rice. The basic objective of a rice milling system is to remove the husk and the bran layers, and produce an edible, white rice kernel that is sufficiently milled and free of impurities.

Depending on the requirements of the customer, the rice should have a minimum number of broken kernels.

*The rice kernel composition*

Most rice varieties are composed of roughly 20% rice hull or husk, 11% bran layers, and 69% starchy endosperm, also referred to as the total milled rice.

In an ideal milling process this will result in the following fractions: 20% husk, 8−12% bran depending on the milling degree and 68−72% milled rice or white rice depending on the variety. Total milled rice contains whole grains or head rice, and brokens. The by-products in rice milling are rice hull, rice germ and bran layers, and fine brokens.

***Paddy quality***

**Mill at the right moisture content (MC)**

A moisture content of 14% MC is ideal for milling. If the MC is too low, high grain breakage will occur resulting in low head rice recovery. Broken grain has only half the market value of head rice. Use a moisture meter to determine the moisture content. Visual methods are not accurate enough.

**Pre-clean paddy before husking**

Use of paddy without impurities will ensure a cleaner and higher quality end product.

**Do not mix varieties prior to milling**

Different varieties of paddy have different milling characteristics that require individual mill settings. Mixing varieties will generally lead to lower quality of milled rice.

***Milling technology***

**Use rubber roll technology for husking**

Rubber roll huskers produce the best quality. Engleberg-type or "steel" hullers are no longer acceptable in the commercial rice milling sector, as they lead to low milling recovery and high grain breakage.

**Use a paddy separator**

Separate all paddy from the brown rice before whitening. Paddy separation after husking will lead to better quality milled rice, and reduce overall wear and tear on the rice mill.

**Consider two-stage whitening**

Having at least two stages in the whitening process (and a separate polisher) will reduce overheating of the grain and will allow the operator to set individual machine settings for each step. This will ensure higher milling and head rice recovery.

**Grade the milled rice**

Installl a screen sifter to remove small brokens and chips from the polished rice. Rice with a large number of small brokens (or brewer’s rice) has a lower market value. The small brokens can be utilized to produce rice flour.

***Management***

**Monitor and replace spare parts regularly**

Turning or replacing rubber rolls, refacing stones, and replacing worn screens regularly will keep milled rice quality high at all times.

**2.3 RICE UTILIZATION**

**Home preparation and cooking[[14]](#footnote-14)**

Washing of milled rice prior to cooking is a common practice in Asia to remove bran, dust and dirt from the food, since rice is often retained in open bins and thus exposed to contamination. During washing some water-soluble nutrients are leached out and removed. Table 41 presents the washing and cooking losses of nutrients from various types of rice. It indicates that a significant amount of protein, ash, water-soluble vitamins and minerals and up to two-thirds of crude fat may be removed during washing. Marketing clean packaged rice will reduce or delete washing steps and prevent or reduce loss of nutrients during washing.

Boiling in excess water results in leaching out of water-soluble nutrients including starch and their loss when the cooking liquor is discarded. For example, 0.8% of the starch was removed on two washings of three milled rices, but 14.3% of the starch by weight was in the rice gruel after cooking for about 20 minutes in 10 weights of water (Perez et al., 1987). Protein removal was 0.4% during washing and 0.5% during cooking. Boil-in-the-bag parboiled rice in perforated plastic bags makes cooking in excess water simple and convenient. In the rice cooker or optimum-water-level method, the leachate sticks to the cooked rice surface as the water gets absorbed by the rice starch. The bottom layer is more mushy than the top layer.

**TABLE 20 - Percent nutrient losses during washing and cooking in excess water**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Nutrient** | **Washinga** | | | **Washing and cookingb** | **Cooking without washingc** | | |
|  | **Raw milled rice** | **Brown rice** | **Parboiled milled rice** | **Milled rice** | **Milled rice** | **Brown rice** | **Parboiled rice** |
| Weight | 01-Mar | 0.3-0.4 |  | 05-Sep | 02-Jun | 01-Feb | 3 |
| Protein | 02-Jul | 0-1 |  | 2 | 0-7 | 04-Jun | 0 |
| Crude tat | 25-65 |  |  | 50 | 36-58 | 02-Oct | 27-51 |
| Crude fiber | 30 |  |  |  |  |  |  |
| Crude ash | 49 |  |  |  | 16-25 | Nov-19 | 29-38 |
| Free sugars | 60 |  |  | 40 |  |  |  |
| Total polysaccharides | 01-Feb |  |  | 10 |  |  |  |
| Free amino acids | 15 |  |  | 15 |  |  |  |
| Calcium | 18-26 | 04-May |  | Jan-25 | 21 |  |  |
| Total phosphorus | 20-47 | 4 |  | 5 |  |  |  |
| Phytin phosphorus | 44 |  |  |  |  |  |  |
| Iron | 18-47 | 01-Oct |  | 23 |  |  |  |
| Zinc | 11 | 1 |  |  |  |  |  |
| Magnesium | Jul-70 | 1 | 1 |  |  |  |  |
| Potassium | 20-41 | 5 | 15 |  |  |  |  |
| Thiamine | 22-59 | Jan-21 | Jul-15 | 11 | 47-52 |  |  |
| Riboflavin | Nov-26 | 02-Aug | Dec-15 | 10 | 3543 |  |  |
| Niacin | 20-60 | Mar-13 | Oct-13 | 13 | 45-55 |  |  |

a Kik & Williams, 1945; Cheigh et al., 1977a; Tsutsumi & Shimomura, 1978: Hayakawa & Igaue, 1979: Perez et al., 1987.

b Cheigh et al., 1977a. 1977b; Perez et al., 1987.

c El Bayâ, Nierle & Wolff, 1980.

Source: Juliano, 1985b.

Increasing the proportion of brokers in milled rice from 0 to 50% by weight increases loss of solids on cooking of raw rice from 13 to 27% (Clarke, 1982). A contributing factor is the shorter cooking time of brokers: the proportionate loss from the experiment was 22% for large brokers and 47% for small brokers.

Boiling in adequate cooking water also reduces the aflatoxin content of milled rice by 50% (Rehana, Basappa and Sreenivasa Murthy, 1979). Pressure-cooking destroys 73% of the aflatoxin, and cooking with excess water destroys 82%.

Boiling reduces the true digestibility of milled rice protein by 10 to 15% but has no effect on other cereal proteins (Eggum, 1973); however, it improves the biological value of the protein such that net protein utilization in rats is not reduced notably because lysine digestibility is not reduced (Eggum, Resurrección and Juliano, 1977), (Table 42). The undigested protein, which passes out of the alimentary system as faecal protein particles, represents the lipid-rich core protein of spherical protein bodies (Tanaka et al., 1978), which is poor in lysine but rich in cysteine (Tanaka et al., 1978; Resurrección and Juliano, 1981), (Table 43). Mutants with reduced levels of minor sulphur-rich fractions of rice prolamin (10 and 16 kd) are being developed to improve the digestibility of the protein of cooked rice, since the minor prolamin fractions are probably in the core fraction. Parboiling further reduces protein digestibility and increases the biological value correspondingly, without any adverse effect on net protein utilization (Eggum, Resurrección and Juliano, 1977; Eggum et al., 1984), (Table 40). The reported true digestibility of cooked milled rice is 88 ± 4% in adults and children (Hopkins, 1981), (Table 28).

Tanaka and Ogawa (1988) found greater amounts of large spherical protein bodies (PB-I) in indica rice (30%) than in japonica rice (20%), (Ogawa et al., 1987) and suggested that the protein of cooked indica rice may be less digestible than that of cooked japonica rice.

**TABLE 21 - Mean nutritional properties of various raw and cooked, freeze-dried milled rices at 14% moisture**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice ty**  **pe** | **Crude protein** | **Lysine** | **Balance dare in five growing rats** | | | | | | |
| **(%Nx6.25 )** | **(g/16 g N)** |
|  |  |  | **True digestibility** | **Biological value** | **Net protein utilization** | **Energy utilization a** | **Starch digestibilitya** | **Lysine digestibilitya** | **Cysteine digestibilitya** |
| **(% of N intake)** | **(% of digested N)** | **(% of intake)** | **(% of intake)** | **(% of intake)** | **(% of intake)** | **(% of intake)** |
| **IR29, IR32, IR480-5-9 b** | 8.9 | 3.6 | 99.7 | 67.7 | 67.5 | 96.8 | 99.9 | 99.9 | 99.5 |
| Raw |
| Cooked,freeze-dried | 9 | 3 5 | 88.6 | 78.2 | 69.2 | 95.4 | 99.9 | 99.4 | 82 |
| **IR58** | 11.8 | 3.5 | 99.1 | 68.8 | 68.3 | 97 | - | - | - |
| Raw c |
| Cooked,freeze-driedd | 12.7 | 3.5 | 85.8 | 73.7 | 63.2 | 92.5 | - | - | - |

a IR29 and IR480-5-9 only

b Eggum, Resurrección & Juliano. 1977.

c IRRI, 1984a.

d Eggum et al., 1987.

**Major processed rice products[[15]](#footnote-15)**

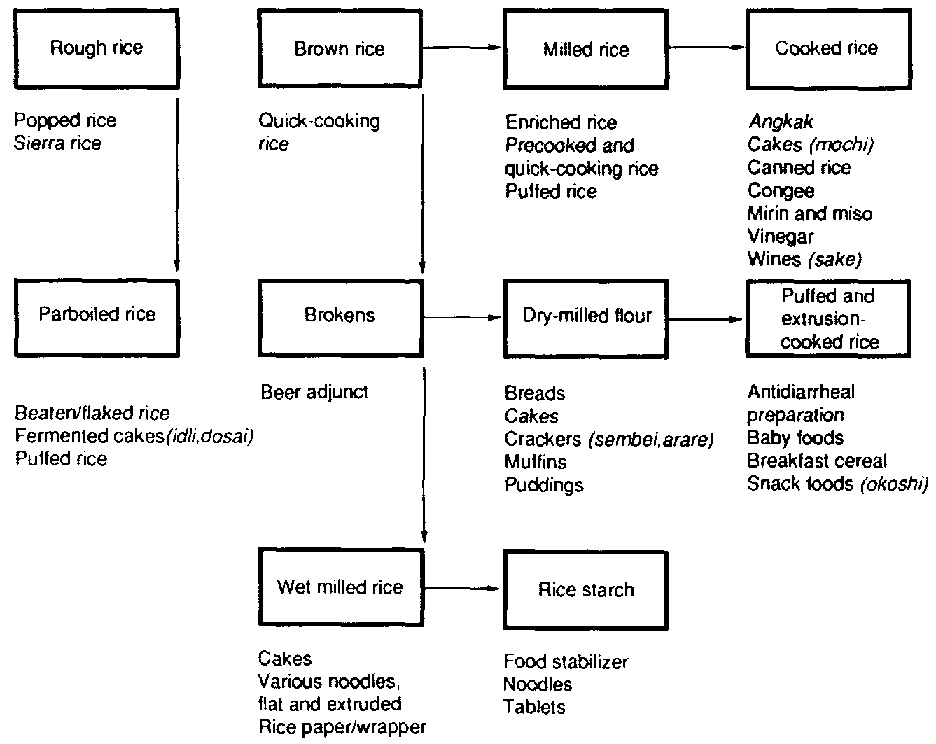
Consumption of processed rice products is probably highest in Japan, where it accounted for about 9.5% of total rice consumption in 1987 (4.8% sake, 1.0% miso, 2.0% crackers, 1.0% flour and 0.4% each packaged rice cake and boiled rice products), (Hirao, 1990). In comparison, processed rice products have accounted for about 2% of rice consumption in the Philippines (Food and Nutrition Research Institute, 1984), about 1% (as noodles) in Malaysia (FAO, 1985) and over 1% in Thailand (Maneepun, 1987).

In countries such as Japan and the Republic of Korea where per caput consumption of boiled rice is decreasing, maintenance of rice consumption is being pursued through the development of new products and the improvement of traditional products in order to maintain total rice production. Japan has the widest range of convenience rice products, including automated cooking equipment for catering (Juliano and Sakurai, 1985). Many national programmes are also looking into the improvement of the quality and shelf-life of traditional rice products (FAO, 1985). Japan's super-rice programme will incorporate selected preferred characteristics of foreign rice into the new Japanese rices (Yokoo, 1990).

Processed rice products may be derived from rough rice, brown rice, milled rice, cooked rice, brokers, dry-milled flour, wet-milled flour or rice starch (Juliano and Hicks, 1993), (Figure 5). The nutrient composition of some rice products is summarized in Table 44.

**Precooked and quick-cooking rices**

Precooked rice is used for rice-based convenience food products in which nonrice ingredients are packed separately and mixed only during heating. Retort rice in Japan is made by hermetically sealing cooked non-waxy and waxy rice in laminated plastic or aluminium-laminated plastic pouches and pasteurizing at 120°C under pressure (Juliano and Sakurai, 1985; Tani, 1985). Steamed waxy rice with red beans accounts for 80% of retort rice in Japan, with an annual production of 8 030 t in 1983 (Tani, 1985) and 4 264 t in 1986 (Iwasaki, 1987). An aluminium-laminated plastic pouch is warmed directly in hot water for 10 to 15 minutes, while plastic pouches may be punctured and heated in a microwave oven for 1 to 2 minutes.



Frozen cooked rice packed in airtight plastic pouches had a production figure of 10 841 t in 1983 in Japan (Tani, 1985); 22 575 t were produced in 1986 (Iwasaki, 1987). Deep freezing without dehydration is the best condition for keeping cooked rice from retrograding (hardening). Frozen rice produced in cooking centres is delivered to chain restaurants where it is heated in microwave ovens and served to customers.

**TABLE 22 - Nutrient composition per 100 g of selected rice products Human food**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Product** | **Moisture energy** | **Food** | **Protein** | **Thiamine flavin** | **Ribo-** | **Niacin** |
| **(g)** | **(kcal)** | **(g)** | **(mg)** | **(mg)** | **(mg)** |
| Instant rice, US | 9.6 | 362 | 7.5 | 0.44 | - | 3.5 |
| Rice, granulated, USa | 7.4 | 383 | 6 | 0.42 | 0.11 | 5.8 |
| Kaset rice-soybean infant food, Thailanda | 5.2 | 401 | 11 | 0.2 | 0.4 | 1 |
| Baby cereals, rice-based, UKa | 4.9 | 386 | 10.9 | 1.6 | 1.2 | 23 |
| Am, thin rice gruel, Philippines | 95.9 | 17 | 0.1 | 0.02 | 0.02 | 0.4 |
| Rice gruel, Philippines | 91.5 | 30 | 0.6 | 0.01 | 0.01 | 0.1 |
| Arroz caldo, rice gruel, Philippines | 83.8 | 63 | 2 | 0.02 | 0.03 | 0.4 |
| Bihon, rice noodles, Philippines | 12.4 | 364 | 5 | trace | 0.01 | 0.2 |
| Fermented rice/black gram idli, India | 45 | 220 | 7.6 | 0.32 | 0.3 | 0.9 |
| Puto, fermented rice cake, Philippines | 46.6 | 214 | 2.8 | 0.01 | 0.01 | 0.4 |
| Chinese waxy rice cake, UK | 29.8 | 290 | 3.5 | trace | 0.02 | 0.9 |
| Bibingka, rice cake, Philippines | 41.5 | 234 | 3.6 | 0.12 | 0.05 | 0.6 |
| Waxy rice bibingka, Philippines | 36.8 | 256 | 2.8 | 0.03 | 0.01 | 1.1 |
| Kutsinta, rice cake with lye, Philippines | 58.9 | 167 | 1.4 | trace | 0.01 | 0.2 |
| Suman, waxy rice cake with lye,Philippines | 52.3 | 191 | 3.2 | trace | 0.02 | 0.5 |
| Suman sa ibos, waxy rice cake with coconut milk, Philippines | 57.5 | 171 | 3.1 | 0.01 | 0.01 | 0.3 |
| **Product** | **Moisture energy** | **Food** | **Protein** | **Thiamine flavin** | **Ribo-** | **Niacin** |
| **(g)** | **(kcal)** | **(g)** | **(mg)** | **(mg)** | **(mg)** |
| Tikoy, waxy rice cake, Philippines | 37.7 | 250 | 2.5 | 0.02 | 0.02 | 0.4 |
| Puto bumbong, purple waxy rice cake,Philippines | 38.5 | 251 | 3.5 | 0.03 | 0.01 | 0.4 |
| Palitaw, waxy rice preparation,Philippines | 51.8 | 206 | 2.6 | 0.04 | 0.02 | 0.7 |
| Kalamay, waxy rice preparation with coconut syrup, Philippines | 48.2 | 208 | 2.7 | 0.01 | 0.01 | 0.3 |
| Espasol, waxy rice product, Philippines | 25.8 | 312 | 4 | 0.06 | 0.04 | 1.1 |
| Tamales, rice flour preparation,Philippines | 75.2 | 100 | 1.3 | 0.01 | 0.02 | 0.4 |
| Puffed rice, US. | 3.7 | 399 | 6 | 0.44 | 0.04 | 4.4 |
| Puffed rice, non-waxy, sweetened | 5.6 | 385 | 4.5 | 0.01 | 0.14 | 1.6 |
| Puffed rice, presweetened, with cocoa, USa | 3.4 | 401 | 4.5 | 0.42 | 0.06 | 6.3 |
| Pinipig, flattened parboiled waxy rice,puffed, Philippines | 3.3 | 392 | 3.1 | trace | 0.04 | 2 |
| Puto seko, toasted rice bread,Philippines | 4.8 | 388 | 6 | 0.06 | 0.02 | 0.5 |
| Rice pudding, canned, UK | 77.6 | 89 | 3.4 | 0.03 | 0.14 | 0.2 |
| Chicken with rice soup,condensed, US | 89.6 | 39 | 2.6 | trace | 0.02 | 0.6 |
| Japanese sake rice wine, 32 proof | 78.4 | 134 | 0.5 | 0 | 0 | 0 |
| Chinese rice wine, 34 proof | 79.1 | 132 | 0 | trace | 0.01 | 0.12 |
| **Product** | **Moisture energy** | **Food** | **Protein** | **Thiamine flavin** | **Ribo-** | **Niacin** |
| **(g)** | **(kcal)** | **(g)** | **(mg)** | **(mg)** | **(mg)** |
| Rice flour, UK | 11.8 | 366 | 6.4 | 0.1 | 0.05 | 2.1 |
| Rice starch | 13.8 | 343 | 0.8 | - | - | - |

a With added vitamins and minerals.

Sources: Food and Nutrition Research Institute, 1980; Watt and Merrill, 1963; Luh and Bhumiratana, 1980; Holland, Unwin and Buss, 1988.

Quick-cooking rices are those that require significantly less cooking time than raw milled rices (15 to 25 minutes). Various methods are employed to fissure raw rice or to dry cooked rice to produce a porous structure. Dry-heat methods include heating milled and brown rice with 57 to 82°C air for 10 to 30 minutes or with 272°C air for 17.5 seconds to fissure the grain. Japanese companies heat brown rice in a countercurrent hot air stream at 105 to 130°C for 30 minutes and quickly cool it to below 30°C (Juliano and Sakurai, 1985). Parboiled brown rice may be made quick-cooking by scouring about 1% by weight of the pericarp to remove the outer water-impervious layer (Desikachar, Raghavandra Rao and Ananthachar, 1965). Precooked quick-cooking rice processes include soak-boilsteam-dry, gelatinize-dry-puff, gelatinize-roll or bump-dry, freeze-thaw, gun puff, freeze-dry and chemical treatments (Roberts, 1972).

Pregelatinized or "alpha" rice production in Japan was 13 900 t in 1983 (Tan), 1985) and 14 500 t in 1986 (Iwasaki, 1987). Cooked rice is quickly dried by heated air to fix the starch in an amorphous state at about 8% moisture. Gelatinized rice is used as an emergency food and as rations in ships and mountain climbing because of its long shelf-life (three years), (Imai, 1990) and light weight (Juliano and Sakurai, 1985). It is consumed after hydration, cooking or warming for about 10 minutes and standing for about 15 minutes. Freeze-dried rice reconstituted by adding hot water to it best approximates cooked rice. Japanese instant rice gruel is prepared from pregelatinized brown-rice flour or flattened grains by adding hot water or cooking over low heat for several minutes and may be used as a weaning food.

In Taiwan Province (China), two kinds of dried cooked rice are produced commercially. One is a Cantonese-style rice congee made from non-waxy (lowamylose) milled-rice brokers, washed, ground in a hammer mill with a 5-mm screen, precooked with six times the volume of water, drum-dried for 3 minutes with a steam pressure of 5 kg/cm2 and a clearance of 1.5 mm, flaked, mixed with dried cooked meat, vegetables, salt, monosodium glutamate and other flavourings and packed in pouches. The other product is guo-ba, a thin block of dried cooked waxy rice. Waxy rice is washed, soaked, cooked in a rice cooker, hand-spread in a thin uniform 0.6 cm layer on teflon-coated perforated trays, baked over a flame at 135°C for 40 minutes or at 165°C for 15 minutes, cut into 6 x 6 cm blocks and sundried to about 12% moisture. The guo-ba may be packaged for future use, may be further flavoured and fried, may be used as a ready-to-eat snack or breakfast food or may be added as an ingredient in cooked dishes. Both products involve spreading the cooked rice into layers by hand, which is both time consuming and a potential source of contamination.

Dry precooked rice cereal is produced by preparing and cooking a cereal slurry, which is then dried in a double-drum atmospheric dryer, flaked and packed (Brockington and Kelly, 1972). The slurry solids, drum speed and temperature and spacing between drums are carefully controlled. Hydrated precooked and readyto-eat infant foods must have the right consistency, soft enough to be swallowed easily but thick enough to feed without spilling. Malt and fungal a-amylase may be added to control the quantity of liquid required to reconstitute the dried cereal and to sweeten it by partial hydrolysis of the starch. Rice-based weaning foods are popular in Southeast Asia, such as the Kaset extrusion-cooked rice and full-fat soybean formulation (Luh and Bhumiratana, 1980). Heat-sensitive ingredients such as milk are preferably added after extrusion, to avoid lysine and cysteine degradation of the protein.

**Noodles**

Flat and extruded round noodles and rice paper are traditionally prepared from wet-milled flour that has been ground using either a stone or a metal mill. The starting material is brokers with a low fat content, preferably freshly milled from aged rice with a high apparent amylose content and a hard gel consistency.

To make flat rice noodles, a wet-milled rice batter with a consistency of 42% rice by weight is placed on a noodle-making machine until the drum is half immersed. The smooth drum is then slowly rotated. The adhering batter is scraped off by a stainless steel sheet set at about a 45° angle and flows onto a moving taut cotton or stainless-steel conveyor belt that carries it into a steam tunnel for 3 minutes for gelatinization (to 62% moisture), (Juliano and Sakurai, 1985; Maneepun, 1987). The sheet dips momentarily into peanut oil before it is folded and cut into appropriate sheets (50 x 50 cm) for direct sale as fresh noodle. Very little starch degradation occurs in the process.

Rice paper and egg roll wrapper are also prepared from wet-milled high-amylose rice batter in Viet Nam, Thailand and Taiwan. A measured volume of rice batter, with the proper consistency, is poured with a flat shallow ladle over taut cheesecloth on top of a steamer. The batter is spread over the whole surface by a circular motion of the ladle and steamed until gelatinized. The sheet is then removed with a rolling motion onto a rolling pin and unrolled onto a slottedbamboo drying tray. Rice paper is thinner than egg roll wrapper and is used as translucent edible candy wrapper. The egg roll wrapper may have some added salt.

A cooked rice slurry with added food colours is poured onto various leaf surfaces, dried and peeled off and used as colourful decorations for homes during the annual May 15 festival at Lucban, Quezon in the Philippines. These edible decorations, kiping, retain the vein patterns of the various leaves on to which they are poured.

Traditionally, extruded noodles (bihon, bijon, bifun, mehon or vermicelli) are prepared from aged high-amylose brokers by wet-milling the steeped rice, kneading it into fist-sized balls, surface-gelatinizing the flour balls (about 500 g) in a boiling water bath until they float, remixing, extruding through a hydraulic press with a die, subjecting the extruded noodles to heat treatment for surface gelatinization, soaking in cold water and sun-drying in racks (Juliano and Sakurai, 1985). Machines in Thailand knead the flour into cylinders that are steamed in portable racks and mixed mechanically into the extruder. Extruders may also be used to cook end kneed premoistened dry-milled flour and then extrude it as noodle at the end of the barrel. Considerable starch degradation occurs during extrusion, such that the gel consistency changes from hard to soft. Protein quality deteriorates very little.

Fermented extruded fresh rice noodle is quite popular in Thailand. Brokens are soaked for three days for fermentation, which reduces the pH from 7 to 3.5, with Lactobacillus spp. and Streptococcus spp. (Maneepun, 1987) and are then processed in the same manner as the unfermented noodle.

Protein decreases from 1.54% after one day of fermentation to 1.14% after three days at 70% moisture.

During wet milling, water-soluble nutrients and damaged starch are lost in the filtration step. Nutrient losses include vitamins, minerals, free sugars and amino acids, water-soluble polysaccharides and protein (albumin) and fat. The wastewater poses a pollution problem. Many Philippine extruded noodle plants use maize starch to minimize the pollution, but maize starch noodle has lower nutritional value (<1% protein) than rice noodle.

**Rice cakes, fermented rice cakes and puddings**

Wet-milled non-waxy or waxy rice flour may be kneaded with water and converted to sweetened rice cake by adding sugar and other ingredients before steaming. A yeast-fermented steamed rice cake (puto) is produced in the Philippines, for which aged, intermediate-amylose rice yields the greatest volume expansion and optimum softness (Perez and Juliano, 1988). Nenkau is a traditional Chinese rice cake and is basically of three types: a sweetened cake made of waxy rice and sugar; a savoury cake with radish, made from high-amylose rice mixed with crushed radish; and a fermented rice cake, made of fermented rice dough of highamylose rice and sugar.

Idli (rice dumpling) and dosai (rice pancake) are prepared in India from a mixture of parboiled milled rice and black gram (Phaseolus mungo), about 3:1 by weight, typically as breakfast foods (Hesseltine, 1979; Steinkraus, 1983). Rice and decorticated black gram are separately washed, soaked 5 to 10 hours in 1.5 to 2.2 times by weight of water and wet-milled separately to give a coarse (0.6 mm) rice flour and a smooth, gelatinous gram paste. The flour and paste are mixed together with 0.8% salt and the thick batter is fermented overnight, steamed (idli) or fried (dosai) and served hot. Ingredients added to idli for flavour include cashew nut, ghee, pepper, ginger, sour buttermilk and yeast. Dosai usually contains less black gram. The batter quality of idli is attributed to the globulin protein and the arabinogalactan of the black gram (Susheelamma and Rao, 1979). Parboiled highamylose rices are suitable for idli. During fermentation, B vitamins and vitamin C increase (Soni and Sandhu, 1989) and phytate is about 50% hydrolysed.

A Philippine rice cake, bibingka, is made from non-waxy and waxy rice flour (wet-milled) with sugar and coconut milk, baked in a banana-leaf lined pan in a charcoal stove with live charcoal on top until brown. Another rice cake, puto kutsinta, is an unleavened cake textured like a stiff pudding and is prepared from wet-milled rice flour with sugar and lye.

Japanese rice cake or paste (mochi) is traditionally prepared from waxy milled rice by washing the milled rice, steaming at 100°C for about 15 minutes to a 40% moisture content, grinding (kneading or using a mortar and pestle), packing in plastic film, pasteurizing for 20 minutes at 80°C and cooling (Juliano and Sakurai, 1985). Recently, gelatinized waxy-rice flour has been directly manufactured by extrusion cooking; it has diverse applications, including mochi. Mochi is usually sliced into pieces (such as cubes), toasted and seasoned with soy sauce or wrapped and eaten as a snack. Preferred waxy rices have a final starch GT of 66 to 69°C (Palmiano and Juliano, 1972). Ready-to-eat mochi is pasteurized under 95°C in packaged containers (Tan), 1985). Annual consumption in Japan was 42 000 t in 1983 and 52 305 t in 1986 (Iwasaki, 1987).

Traditional Philippine waxy-rice snack foods or desserts include rice cakes (suman) made from milled rice. Suman sa antala and suman sa ibos are cooked with coconut milk and salt. Suman sa antala is wrapped in heat-wilted banana leaves and steamed for 30 to 35 minutes, but for suman sa ibos the waxy rice/coconut milk mixture is packed loosely into nipa or palm leaves (ibos) and boiled for 2 hours or until done. In suman sa lihiya, the steeped waxy rice is treated with lye,, wrapped in banana leaves and boiled for 2 hours or until done. Suman sa ibos is usually served with sugar, while suman sa lihiya is served with grated-coconut and sugar. Low-GT waxy rices are preferred for these cakes. Wetmilled purple waxy rice is added to waxy rice in preparing puto bumbong, wherein the rice flour is cooked by steaming in bamboo cylinders. Food colouring is now used to obtain the purple colour of the product, which is also eaten with grated coconut and sugar. Palitaw is made from a flattened wet-milled batter of waxy rice dropped into boiling water; after the cakes float they are dropped into cold water to prevent them from sticking to each other. They are drained and served with grated coconut and pounded sesame seeds. Espasol is made from coconut milk and sugar syrup to which cooked waxy rice is added, followed by toasted and powdered waxy rice. The paste is rolled with a rolling pin and cut into various shapes. Rice powder is sprinkled over the paste to prevent sticking. Tamales contains toasted, ground rice and a mixture of peanuts, sugar, spices and meat which is cooked until thick enough to hold its shape. It is then wrapped in banana leaves and steamed for 2 hours.

The Japanese rice pudding uiro consists of waxy rice flour, cornstarch, sugar, water and flavourings that are mixed and steamed for 60 minutes at 100°C and served with sweet bean curd, green tea, coffee, cherries and other fruits (Juliano and Sakurai, 1985). Low-amylose, short- to medium-grain rices are used in preparing Chinese rice pudding (Li and Luh, 1980). The rice is cooked in boiling water, strained and mixed with milk before the completion of cooking. Egg yolk, sugar, vanilla and light cream are added together with a variety of fruit combinations. Canned rice pudding in a milk base with added fruit has been available in Australia and the United Kingdom for more than two decades.

**Expanded (puffed, popped) rice products**

Puffed and popped rices are traditional breakfast cereals and snack foods (Juliano and Sakurai, 1985). Raw rice is traditionally popped by heating rough rice (13 to 17% moisture) at about 240°C for 30 to 35 seconds or at 275°C for 40 to 45 seconds or in an oil bath at 215 to 230°C. The hull contributes to pressure retention before popping as evidenced by the lower popping percentage of brown rice. Good popping varieties have a tight hull and a significant clearance between hull and brown rice and when freshly harvested are free of grain fissures (Srinivas and Desikachar, 1973). Tightness of hull, grain hardness and degree of translucency could explain 80% of the variation in popping expansion among 25 rice varieties (Murugesan and Bhattacharya, 1991).

Flaked or beaten brown rice and parboiled milled rice may be converted to puffed rice by heating in hot air or roasting in hot sand (Juliano and Sakurai, 1985; Villareal and Juliano, 1987). With normal parboiled milled rice, puffed volume is directly proportional to the severity of parboiling

(equilibrium water content of steeped grain prior to parboiling) and is highest for waxy rice (Antonio and Juliano, 1973). Puffed waxy and low-amylose rices tend to have a higher puffed volume than intermediate- to high-amylose rices only when grains are incompletely parboiled or cooked before oil puffing (Villareal and Juliano, 1987). However, with increasing temperature and period of roasting of rough rice, high-amylose rice (specifically 27%) gives the maximum puffed volume for roasted beaten rice (Chinnaswamy and Bhattacharya, 1984). Puffed non-waxy rice and flattened waxy rice are caramelized and moulded and are common snack foods in the Philippines. A typical Japanese rice cake, okoshi, is made of puffed broken rice mixed and moulded with millet jelly, sugar and flavouring.

Gun-puffing of moist milled rice may be considered as puffing rather than popping since the grains are gelatinized prior to expansion. The expansion ratio was higher for waxy milled rice than for non-waxy rice (Villareal and Juliano, 1987). The expansion ratio for gun-puffed milled rice or oil-puffed parboiled or boiled milled rice correlated negatively with protein content, except for those rices parboiled at zero steam pressure before oil-puffing.

Continuous explosion-puffing of brown rice, developed in Japan in 1971, uses a long heating pipe wherein grains are dispersed and conveyed by a high-velocity stream of superheated steam (Sagara, 1988). After the rice has been heated and dried within 3 to 10 seconds, it is discharged into the atmosphere through a rotary valve to explosion-puff. A brown rice expansion ratio of 5.4 is obtained at 6 kg/cm2 pressure and an outlet steam temperature of 200ºC. The puffed product has a starch digestibility of 94% after 15 minutes of boiling. Thiamine is not destroyed at 200°C or lower but is completely destroyed at an outlet steam temperature of 240°C (Sagara, 1988).

In developed countries, dry rice breakfast cereals include rice flakes, ovenpuffed, gun-puffed or extruder-puffed rice, shredded rice cereal and multi grain cereals (Brockington and Kelly, 1972; Luh and Bhumiratana, 1980). These are of the ready-to-eat type in which the rice starch provides texture-modifying properties and rice also imparts its own special flavour. Among the important properties of a ready-to-eat cereal is "bowl life", or the ability to retain its texture and crispness in milk while being eaten.

Moisture-proof packaging is critical for optimum shelf-life. While low-amylose, low-GT rices are used for breakfast cereals in the United States, interrnediate- and high-amylose rices are used in the Philippines, but the degree of cooking must be controlled to obtain an acceptable puffed volume from the grain. Most cereals are enriched with B vitamins and with minerals, particularly iron.

**Baked rice products**

For those suffering from coeliac disease, a yeast-leavened bread of 100% rice flour has been successfully developed, consisting of 100 parts rice flour, 75 parts wafer, 7.5 parts sugar, 6 parts oil, 3 parts fresh compressed yeast, 3 parts hydroxypropyl methylcellulose and 2 parts salt (Bean and Nishita, 1985). Although all non-waxy rices produce breads of equivalent appearance, only lowamylose, low-GT rices give a soft-textured crumb. Intermediate-amylose, intermediate-GT rices give sandy, dry crumb characteristics. However, among lowGT rices low-amylose rice gave a lower loaf volume than did intermediate- and high-amylose rices (IRRI, 1976). Wet-milled flour gave a better texture than drymilled flour. An extended shelf-life should improve the popularity of this product.

A medium-grain low-amylose rice flour: waxy rice flour ratio of 3:1 in place of wheat flour produced satisfactory muffins for gluten-sensitive individuals (Stucy Johnson, 1988).

For bread baking in Japan, 10 to 20% rice flour is generally mixed with wheat flour as a diluent, depending on the gluten strength of the wheat flour (Tan), 1985). A recent Japanese formulation consisted of 60% rice flour, 30% wheat flour and 10% vital gluten. Similar dilutions of wheat flour with rice flour and other starchy flours have been developed for bread-making in several countries, but the GT of the starch should preferably be low (<70°C), (Bean and Nishita, 1985).

Rice flour has also been used in making a Pakistani bread similar to roti, the flat unleavened bread commonly made from wheat flour (Juliano and Sakurai, 1985). The preferred bread, similar to a wheat chapatti, is puffed, semi-light, flexible, uniformly round and firm, but not rough. Red rices, such as Dwarf Red Gunja, are preferred in some Sind villages for Pakistani rice bread. Rice flour may also be added to wheat flour in a proportion of up to 15%; 21% rice flour in chapatti results in a still acceptable but difficultto-fold texture.

Fresh pregelatinized starch is used for the preparation of wheatless bread; the starch (16% by weight) acts as a binder in place of gluten, as in extruded rice noodles (Satin, 1988). The method is applicable to rice flour, but the crust properties are not as good as those of wheat bread and have to be improved. Dry, pregelatinized rice flour may possibly be used to produce this bread faster without any problem of incomplete starch gelatinization during baking in the presence of sucrose.

A layer-cake formula containing 100% rice flour was also developed for wheat-free diets (Bean and Nishita, 1985). It consists of 100 parts rice flour, 80 parts sugar, 15 parts oil and 5 to 7 parts double-acting baking powder. Lowamylose, low-GT rices are preferred for this formula; intermediate-amylose, intermediate-GT rices give a sandy, dry texture. A high sucrose level increases starch GT; thus in 50% sucrose low-GT rices have a GT of 80ºC while intermediate-GT rices have a GT of 92°C. When the sucrose level is reduced to give a GT of 80ºC for the intermediate-GT rice, the volume and contour of the cakes improve, but the sandy texture remains. Hydrating the rice flour by intense mixing of the flour and water and folding of the hydrated mixture improve the texture and volume of the cake (Perez and Juliano, 1988).

Baked Japanese rice cakes or rice crackers include senbei and arare. A rare is a cracker made from boiled waxy rice pounded into rice cake, stored at 2 to 5°C for two to three days to harden, cut, dried to 20% moisture at 45 to 75°C and baked. Senbei is a cracker-like snack made of cooked non-waxy rice flour kneaded and rolled into sheets, cut, dried at 70 to 75°C to 20% moisture, tempered for 10 to 20 hours at room temperature, redried at 70 to 75°C to 10 to 12% moisture and baked at 200 to 260ºC, without the cooling treatment. Arare expands more during baking, has a soft texture and dissolves easily in the mouth. Senbei is harder and rougher. Sesame seeds, pieces of dried seaweed, peanuts, pulverized shrimp, cheese or spices may be mixed with the rice dough as desired. Extruder-type kneaders are used for mixing the gelatinized rice. Rice cracker production in Japan in 1983 was 103 000 t of arare and 118 000 t of senbei (Tani, 1985) and in 1987 was equivalent to 215 000 t of brown rice (Hirao, 1990).

Non-waxy rice cakes or crackers (xianggao) are prepared from both low- and high-amylose rices in China. The high-amylose cake is harder, whiter and more crispy than the low-amylose cake. A similar rice product made in the Philippines from intermediate- to high-amylose rice is called puto seko. These crackers break readily on handling.

**Canned rice**

In the United States, the preferred canned rice product is white, with separate noncohesive grains, minimal longitudinal splitting and fraying of edges and ends and a clear canning liquor (Burns and Gerdes, 1985). Long-grain (intermediateamylose) parboiled rices are preferred in most canning formulations because of the required cooked rice stability. Non-parboiled high-amylose rices, particularly those with a hard gel consistency, are also suitable, but the texture may be too hard. A pH below 4.6 is recommended for canned rice to reduce microbial contamination because retorted canned rice may not be completely sterilized.

In Japan, low-amylose milled rice is placed in cans with water, broth or another seasoning, steamed for about 30 minutes and sealed and sterilized in a retort at 112°C for 80 minutes (Juliano and Sakurai, 1985). Canned rice is heated in boiling water for 15 minutes before serving. Canned seasoned cooked rice is marketed primarily as military rations and as emergency foods. Intermediate-amylose rice is used in canned rice for the military in the Philippines. Annual production of canned rice in Japan was 1 472 t in 1983, but it is declining in popularity (Tan), 1985) with only 1 159 t produced in 1986 (Iwasaki, 1987).

Both wet- and dry-pack canned rices are produced in Taiwan (Chang, 1988). Daily production of wet-pack rice is 360 000 easy-to-open 340-ml cans, while the production of dry-pack rice is very limited. Wet-pack canned rice preparations, usually called rice congee, use waxy rice and are all sweetened; the most popular formula includes waxy rice as a base together with dried longans, red beans, peanuts, oatmeal and sugar. Low-amylose rice is used for dry-pack fried rice.

**Fermented rice products**

Various waxy rice wines are prepared by fermenting steamed waxy milled rice with fungi and a yeast starter (Steinkraus, 1983; Juliano and Sakurai, 1985). A sweet product is first produced, which is then converted to alcohol as fermentation progresses. The liquid is removed by decantation. Examples are Chinese laochao, Thai khaomak, Malaysian tapai, Indonesian tape ketan and Philippine tapuy. Red rices are preferred for tapuy and are often roasted before cooking (Sanchez et al., 1989). Ethanol conversion is higher for waxy and low-amylose rice than for intermediate- and high-amylose rice during tapuy production; undigested starch is mainly amylose (Sanchez et al., 1988).

Rice wine production in Taiwan uses 67 000 t of milled rice annually and uses either Aspergillus oryzae (shao-hsing wine) or Rhizopus sp. (hua-tiao) for saccharification (Chang, 1988). Overmilled waxy rice (20% bran polish) is washed, steeped in water, steamed, inoculated with A. oryzae spores and incubated for 45 hours at 35 to 38°C for a low-amylose brown rice starter.

Ragi-type starters (bubod in the Philippines) are available in the markets of most Asian countries (Steinkraus, 1983). They are usually small (3 to 6 cm), round, flattened cakes of rice flour on which the desired microorganisms have been grown. The cakes are either air-dried or sun-dried and the dehydration occurs simultaneously with growth of the organisms. Micro-organisms include the mould Rhizopus sp. or combinations of the essential yeasts and moulds required for the different types of alcoholic fermentations.

Rice is the sole cereal substrate in Japanese rice wine such as sake (Yoshizawa and Kishi, 1985). The raw material is highly milled rice (25 to 30% bran polish by weight of brown rice) with low arnylose, low GT and a white core, characteristics that facilitate swelling, cooking and penetration by the mycelia of A. oryzae. Overmilling lowers protein (5 to 6%) and non-starch lipids (0.1%) and also potassium and phosphorus levels. Steamed rice is inoculated with koji, a culture of A. oryzae grown on steamed rice and seed mash. Sake yeast is grown on koji steamed rice containing 70 ml lactic acid per 100 litres of water at 12°C.

Three more additions of materials are made to maintain fermentation. About 500 000 t of milled rice were used for sake in Japan in 1985 (Tan), 1985).

Rice milk has been used as a substitute for animal milk and milk powder and may be prepared either from puffed rice flour or from wet milled flour with sugar and peanut oil for flavouring. Brown rice gives a better-quality milk than milled rice, and a formulation of 3.5% (wt/vol.) of brown rice, 2% peanut oil and 7.5% sugar gave the best sensory score (Lin, Shao and Chiang, 1988). Rice milk contains 87.7% moisture, 0.8% protein, 0.8% fat, 0.1% crude fibre, 0.1% ash and 10.4% carbohydrate; it has 11% total solids and viscosity of <3 poise. Use of bacterial amylases to hydrolyse the starch can increase the solids content of the milk without unduly increasing the milk viscosity (Mitchell, Mitchell and Nissenbaum, 1988).

Mirin is a clear, sweet drink made by adding steamed waxy rice and koji to shochu, a gin-like alcoholic beverage obtained by distilling a type of sake made from broken indica rice. The mixture is allowed to ferment in the presence of 40% ethanol from shochu until the rice starch is converted to sugars (two months at 25 to 30ºC). After filtration and treatment with tannin and gluten and refiltering, the bottled mirin contains 14% ethanol and 45% sugars. It is used either for drinking (sweetened sake) or for seasoning Japanese dishes. Mirin production in 1986 in Japan was 78 000 kl (Sagara, 1988).

Rice vinegar results from the completion of the rice starch fermentation and is a traditional Japanese and Chinese product (Iwasaki, 1987). Acetic acid fermentation is carried out by mixing seed vinegar with the rice wine and takes one to three months. The product is ripened, filtered, pasteurized and bottled (Lad, Chang and Luh, 1980). It has 4 to 5% total acidity (mostly acetic acid, plus some lactic and succinic acids). Rice vinegar production in Japan was 40 000 kl in 1983 (Tani, 1985) and 52 000 kl in 1986 (Sagara, 1988).

Broken rice, together with maize grits, is an adjunct in beer manufacture in the United States and Japan (Yoshizawa and Kishi, 1985). Rice is preferred to maize because of its lower protein and fat content (<1.5%). Broken rice is obtained from regular milling of brown rice in most countries, except in Japan, where it is milled from broken brown rice. Broken rice must be free from bran contamination to reduce protein and fat content. Low-GT, low-amylose rices are used because intermediate-GT, intermediate-amylose rices are relatively resistant to starch liquefaction. Rice seed is not used for malting in place of barley because of its lower a-amylose production (IRRI, 1988b).

Other fermented rice products include Japanese miso, Sierra rice (amarillo or requemado) from Latin America and angkak (anka, red rice). Miso is a traditional Japanese brown seasoning paste principally used for a breakfast soup. It is prepared from koji (A. oryzae) from milled rice mixed with cooked and minced soybean, salt and a starter of cultured yeast and lactic acid bacteria. The ingredients are fermented in covered vats at 25 to 30°C for one to three months (Wang, 1980). The rice-to-soybean ratio is about 2: 1. Japanese miso production in 1986 was 471 000 kl (Sagara, 1988). Sierra rice is derived from moist rough rice fermented by the micro-organisms that are naturally present with heating up to 50 to 70°C. The grain becomes yellow to brown and is essentially precooked and predigested. Angkak may be produced by Monascus purpureus mould on cooked rice at 35% moisture and pH 6.5 at room temperature (Dizon and Sanchez, 1984). It is used as a colouring agent for food, such as fermented fish (Hesseltine, 1979).

**Rice flours and starch**

Rice flour in Japan is made from both waxy and non-waxy rices and from both raw and gelatinized rice. It is milled by rolling, pounding, shock-milling, stone-milling, milling in a lateral steel mill and wet milling in a stone mill. In 1985, rice flour production in Japan included 67 000 t from raw rice plus 140 t from pregelatinized rice (Tani, 1985). In 1987, rice flour production used 105 000 t of brown rice (Hirao, 1990).

A tea prepared from roasted brown rice in Japan used 23 800 t of non-waxy and 1 200 t of waxy rice in 1985 (Tan), 1985). Production in 1986 was 20 000 t (Sagara, 1988).

High-protein rice flours for early childhood feeding may be obtained from cooked milled rice by destarching treatment with a-amylase (Resurrección,

Juliano and Eggum, 1978; Hansen et al., 1981). A high-fructose rice syrup and a high-protein rice flour have been produced from broken rice using a-amylase, glucoamylase and glucose isomerase. This procedure obtained an 80% glucose yield from brokers (91% starch basis) which was converted to 50% glucose, 42% fructose and 3% maltose (Chen and Chang, 1984). The high-protein flour (28% protein) was recovered in 30 to 32% yield. Others have obtained 80% protein flour Resurrección Juliano and Eggum, 1978). Maltodextrins are also produced from milled rice flour at 80°C using heat-stable a-amylase (Griffin and Brooks, 1989).

Rice starch production involves mainly wet milling of brokers with 0.3 to 0.5% sodium hydroxide to remove protein (Juliano, 1984). Brokens are steeped in alkali solution for 24 hours and are then wet milled in pin mills, hammermills or stone-mill disintegrators with the alkali solution. After the batter is stored for 10 to 24 hours, fibre (cell wall) is removed by passing it through screens; the starch is collected by centrifugation, washed thoroughly with water and dried. Protein in the effluent may be recovered by neutralization and the precipitated protein used as a feed supplement.

In the European Economic Community (EEC), about 8 800 t of broken rice are processed annually to about 7 000 t of starch in five to six plants in Belgium, Germany, Italy and the Netherlands (Kempf, 1984). The starch is used exclusively as a human food, largely for baby foods and also in extruded noodles. Egypt, Syria and Thailand also produce rice starch.

**Rice bran and rice-bran oil**

Rice bran has been an extremely popular source of dietary fibre because of the hypocholesterolaemic property of its oil fraction. Stabilized rice bran has been made available by the use of the Brady extruder in the United States to stabilize the full-fat bran by inactivating its lipase (Saunders, 1990). It is finding application in breakfast cereals, snack foods and bakery products. Stabilized rice bran has been incorporated into whole-wheat bread, muffins, peanut butter cookies and oatmeal cookies at levels of up to 20%. The 3 to 8% sugar content of rice bran may also contribute to oven browning. The high water absorption capacity of rice bran helps maintain moisture and freshness and therefore improves shelf-life. Its foaming capacity aids in air incorporation and leavening.

In tropical Asia, food applications of rice bran will have to await the reduction of hull contamination of rice bran from the use of Engelberg mills. However, stabilized rice bran is a good poultry feed since its trypsin inhibitor has been inactivated by extrusion cooking.

Rice-bran oil production was about 679 000 t in 1990 (FAO Statistics Division data) or about 13% of potential production based on 7% bran from rough rice, 15% oil recovery from bran and a world rice production of 507 million tonnes. The principal producers of rice bran oil are India (370 000 t), Japan (83 000 t) and China, including Taiwan (122 000 t).

Rice-bran oil has an iodine absorption number of 92 to 115 and contains 29 to 42% linoleic acid and 0.8 to 1.0% linolenic acid (Jaiswal, 1983). It is considered a salad oil rich in vitamin E and in various plant sterols (Juliano, 1985b).

**Rice types preferred for rice products**

Most rice products have a preferred amylose type which is related to the preferred rice type for boiled rice consumption in the country (Table 45). All rice types are used for parboiled rice, but usually intermediate- and high-amylose rices are used in Thailand and the United States. High-amylose rices are used in Bangladesh, India, Pakistan and Sri Lanka. Canned, precooked and quick-cooking rices, expanded rice products, rice cereals and snacks are of the type preferred for boiled rice. Low-GT rices are preferred for fermented products since the rice starch can be gelatinized at 70°C and therefore requires less cooling before inoculation. Low-fat or highly milled rice, preferably freshly milled to minimize rancid odours, is preferred for rice products. Waxy rices are preferred for desserts and sweets because of the slower rate of hardening of the boiled or steamed rice starch.

**METHODOLOGICAL APPROACH**

In order to analyze the life circle of rice products in Asia, a survey will be designed asking the producer and consumers for relevant information on production, consumption, utilization and market of rice.

As said above, rice is an important cereal crop for farmers in semi-arid areas in Asia.

It has been traditionally cultivated for home consumption, but in recent years market demand has increased. This offers new opportunities for smallholders to commercialize production, which is seen as a pathway for prosperity in the dry lands. Understanding production, consumption and utilization patterns for rice is important to study diet habits and food security of populations, and to develop strategies and awareness campaigns to promote and increase rice consumption: obtaining more information about utilization is one of the most important pre-condition for starting to consume it. Information about utilization is also the most important requirement to increase the consumption.

One strategy for the promotion of rice consumption is to point out the high nutritional value of this crop: rice crop would benefit from information campaigns about its nutritional value.

The survey is designed to interview consumers at three different market outlets to find out where consumers buy the cereal: supermarkets, small retail shops and open-air markets, in order to understand how the urbanization processes change the shopping behavior and highlights the importance of making rice available.

In addition, households are grouped into three different classes: low, middle and high income, to capture consumption habits of different income levels in rural and urban areas, for production and non-production zones.

To understand if rice is bought as grain and/or flour, it is important in order to comprehend the final utilization of the crop and its consumption.

It can also be useful to understand the reasons why some respondents may not consume rice (availability, price issues, etc.).

**SURVEY CONSTRUCTION AND INFORMATION NEEDED**

**EXAMPLE OF IMPACT ON COMMODITY EXTRACTION RATES**

Farmers = Sellers; Traders = Buyers; Households = Final consumer

QP = Quantity Produced

QS = Quantity Sold (Commercial Sale) = A1+B1+C1+…+N1 = 100% = Total quantity available to be processed

QP - QS > 0 = Stored, kind payments, seed, etc…

Total Quantity Processed = A2+B2+C2+…+N2 = 100% = Total quantity for final consumption

**Extraction Rates =**

RICE

**SOLD** QUANTITY

FEED

FOOD INDUSTRY

**A1%**

**B1%**

**C1%**

NON-FOOD INDUSTRY

RICE **PRODUCED**QUANTITY

**QP**

**QS**

OTHER BUYERS

**N1%**

\* e.g. Fermented beverages, infant food, etc.

**PROCESSED PRODUCTS 1ST LEV.**

**4TH LEV.**

**3RD LEV.**

**2ND LEV.**

GLUCOSE & DEXTROSE

GLUTEN

STARCH

MILLED HUSKED RICE

RICE BRAN OIL

MACARONI

LIQUID MARGARINE

GLUTEN & MEAL

HYDROGENATED

MARGARINE

DREGS

BEV. DIST.

CEREAL PREP. n.e.s.

NON FOOD ALC.

DREGS

RICE FLOUR

DREGS

RICE FERM. BEV.

BREAKFAST CEREALS

DREGS

BEER

**B2c%**

**B2b%**

**B2a%**

**A2a%**

CAKE OF RICE

BROKEN RICE

BREAKFAST CEREALS

MILLED PADDY RICE

**B2%**

BRAN

HULLS

BRAN

**A2**b**%**

HUSKED RICE

HULLS

**A2%**

FOOD INDUSTRY

**INFORMATION NEEDED FROM SELLERS, BUYERS AND CONSUMERS**

* Respondent details
* Rice physical characteristics + details
* Rice production and utilization + details
* Percentage of rice sold
* Main purpose of production of the holding + details
* Other economic production activities of the holding + details
* Use of good agricultural practices + details
* Use of organic agricultural practices + details
* Rice consumption (market) + details
* Land use land tenure + details
* Household food security + details
* …….

**PILOT DRAFT**

**Legend**:

Green cells: confirmed

Yellow cells: optional

The survey contains a list of information needed to update the extraction rates in staple food commodity trees.

It has to be better designed; information should be revised, adjusted and additional information might be needed.

The same survey can be used for all commodities in all countries, paying attention to local recipes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1. **SECTION TO BE FILLED IN BY FARMERS**   **(rice sellers)** | | | |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Respondent details:** |  |  |  |
|  |  | Name/Title: |  |  |
|  |  | Age (years) |  |  |
|  |  | Male/Female |  |  |
|  |  | Complete address |  |  |
|  |  | Tel: |  |  |
|  |  | Email: |  |  |
|  | **RICE PHYSICAL CHARACTERISTICS** | | | |
|  | Type of rice produced per typology: |  |  |  |
|  | **Bangladeshi varieties** |  |  |  |
|  |  | Chinigura Rice |  |  |
|  |  | Balam Dhan |  |
|  |  | Bashmoti Rice |  |
|  |  | Kalijira Rice |  |
|  |  | BINA Dhan |  |
|  |  | Binni Rice |  |
|  |  | BrriDhan |  |
|  |  | Digha Dhan |  |
|  |  | Hori Dhan |  |
|  |  | Irri Rice |  |
|  |  | Miniket Rice |  |
|  |  | Hamim |  |
|  |  | Balam-small Red |  |
|  |  | Balam-small White |  |
|  |  | Pakh Beruin |  |
|  |  | Khara Beruin |  |
|  |  | Raujan |  |
|  |  | Kathali Beruin White |  |
|  |  | Kathali Beruin Red |  |
|  |  | Akia Beruin Red |  |
|  |  | Akia Beruin White |  |
|  |  | Modhu Beruin Red |  |
|  |  | Modhu Beruin White |  |
|  |  | Mou Beruin |  |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  |  | Lathial - 7 Red |  |  |
|  |  | Lathial - 7 White |  |
|  |  | Lapha |  |
|  |  | Kalo Beruin |  |
|  |  | Shail dhan |  |
|  | **Cambodian varieties** |  |  |
|  |  | Phka Malis |  |
|  |  | Neang Khon |  |
|  |  | Phka Khnei |  |
|  |  | Neang Minh |  |
|  |  | Phka Romdul |  |
|  |  | Bonla Pdao |  |
|  |  | Sen Kro Ob |  |
|  |  | Sen Pi Da |  |
|  |  | Cammalis |  |
|  | **Lao / Thai varieties** |  |  |
|  |  | Glutinous rice |  |
|  | **RICE PRODUCTION** | | | |
|  | **Primary rice production** |  |  |  |
|  |  | Area Harvested (Ha) | FAO Prod. Quest. |  |
|  |  | Production (MT) | FAO Prod. Quest. |  |
|  | **Producing rice mainly:** |  |  |  |
|  |  | For home consumption | WCA |  |
|  |  | For sale | WCA |  |
|  |  | Forms of in-kind payment | WCA |  |
|  | **Sold rice for:** |  |  | Utilization data refer to the use of crops in the country during the reference period.  On the utilization side a distinction is made between the quantitites used for food, seed, feed, liquid biofuels and industrial utilization. The general utilizations concept further include waste and imported/ exported quantities, which are not part of this survey.  Please provide the utilization in metric tonnes (MT) for the primary crops produced in your country. |
|  |  | Feed | FAO Prod. Quest. | Feed refers to quantities fed to animals, wether direct or used to produce compound feed. |
|  |  | Food industry | FAO Prod. Quest. | Food refers all quantities available for human consumption, either direct by the producers, available for human consumption at the retail level or processed for food use. |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  |  | Non-food industry (Rice manufacturing) | WCA | Includes a whole range of activities associated with transforming raw materials into new products. For households, the most common manufacturing activities are f**ood processing**, making clothes and other textile materials, tanning, and making wood products. |
|  |  | Storage |  |  |
|  |  | Seed | FAO Prod. Quest. | Seed covers quantities used for reproductive purposes |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1. **SECTION TO BE FILLED IN BY TRADERS**   **(rice buyers/industry)** | | | |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **PROCESSING METHODS** |  |  |  |
|  | **Rice to be processed** |  |  |  |
|  |  | Total quantity of rice available to be processed |  |  |
|  | **Producer industry structure** |  |  |  |
|  |  | High tech production | MOA, NSO |  |
|  |  | Low tech production | MOA, NSO |  |
|  | **Traditional processing methods** |  |  |  |
|  |  | Quantity of rice processed by grinding whole grain |  |  |
|  |  | Quantity of rice processed into malted grains |  |  |
|  |  | Quantity of rice processed into parboiled grains |  |  |
|  | **Industrial processing methods** |  |  |  |
|  |  | Quantity of rice grains milled semi-wet |  |  |
|  |  | Quantity of rice grains milled wet |  |  |
|  | **Rice milled on a commercial scale** |  |  |  |
|  |  | Quantity of rice processed by abrasive decortication |  |  |
|  |  | Quantity of rice processed by rubbing techniques |  |  |
|  |  | Quantity of rice processed by roller mills |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **PROCESSED FOOD - RICE TREE** | |  |  |
|  | **Selected derived rice commodities from FAO Rice Commodity Tree** |  |  |  |
|  | **Flour1** |  |  |  |
|  |  | Quantity of flour of rice produced |  |  |
|  |  | Quantity of starch of rice produced |  |  |
|  |  | Quantity of gluten of rice produced |  |  |
|  |  | Quantity of isoglucose of rice produced |  |  |
|  |  | Quantity of other fructose and syrup produced |  |  |
|  |  | Quantity of glucose and dextrose produced |  |  |
|  |  | Quantity of gluten feed and meal produced |  |  |
|  | **Bran2** |  |  |  |
|  |  | Quantity of bran of rice produced |  |  |
|  | **Rice germ** |  |  |  |
|  |  | Quantity of germ of rice produced |  |  |
|  |  | Quantity of rice cake produced |  |  |
|  |  | Quantity of rice oil produced |  |  |
|  |  | Quantity of margarine produced |  |  |
|  |  | Quantity of hydrogen oils produced |  |  |
|  |  | Quantity of liquid margarineproduced |  |  |
|  |  |  |  |  |
|  | **Breakfast cereals** |  |  |  |
|  |  | Quantity of breakfast cereals produced |  |  |
|  | **Cereal preparation** |  |  |  |
|  |  | Quantity of rice based preparation produced |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Beverages** |  |  |  |
|  |  | Quantity of rice malted to produce fermented beverages |  |  |
|  |  | Quantity of rice malted to produce unfermented beverages |  |  |
|  |  | Quantity of beer of rice produced |  |  |
|  | **Infant food** |  |  |  |
|  |  | Quantity of rice malted to be incorporated into infant cereals |  |  |
|  | **Other processed products** | Any other processed products (please specify) |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1. **SECTION TO BE FILLED IN BY HOUSEHOLDS**   **(rice buyers/industry)** | | | |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **RICE CONSUMER MARKET** |  |  | <http://oar.icrisat.org/7245/1/C_Schipmann_Schwarze_et_al_2013_ISEDPS_10.pdf> |
|  | **Type of household consuming rice on a monthly basis** |  |  |  |
|  |  | Urban |  |  |
|  |  | Rural |  |  |
|  |  | Non-producer |  |  |
|  |  | Producer |  |  |
|  |  | Low income |  |  |
|  |  | Middle income |  |  |
|  |  | High income |  |  |
|  | **Monthly consumption of rice on a household level, quantity** |  |  |  |
|  |  | Bought as grain |  |  |
|  |  | Bought as pure flour |  |  |
|  |  | Bought as blended flour |  |  |
|  |  | Mean amount bought (kg) |  |  |
|  |  | Amount bought as grain (kg) |  |  |
|  |  | Amount bought as pure flour (kg) |  |  |
|  |  | Amount bought as blended flour |  |  |
|  | **Utilization of rice by consumers** | e.g.: |  | A deeper research on regional recipe to be conducted |
|  |  | Hot Corn with Chimichurri Butter |  | Chile |
|  |  | Corn-Flour Patties (Sopes) |  | Mexico |
|  |  | … |  | … |
|  |  | … |  | … |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Future demand for rice and reasons for changing demand** |  |  |  |
|  | **Demand** |  |  |  |
|  |  | Increasing |  |  |
|  |  | Decreasing |  |  |
|  |  | Constant |  |  |
|  | **Reasons if increasing** |  |  |  |
|  |  | Family size |  |  |
|  |  | Availability |  |  |
|  |  | Taste |  |  |
|  |  | Cheap |  |  |
|  |  | Healthy |  |  |
|  |  | Own cultivation |  |  |
|  |  | Easy to blend |  |  |
|  |  | Habit |  |  |
|  |  | Learned utilization |  |  |
|  |  | Increased income |  |  |
|  | **Reasons if decreasing** |  |  |  |
|  |  | Family size |  |  |
|  |  | Expensive |  |  |
|  |  | Taste |  |  |
|  |  | Not available |  |  |
|  |  | Decreased income |  |  |
|  | **Reasons if constant** |  |  |  |
|  |  | Family size |  |  |
|  |  | Consume enough |  |  |
|  |  | Dificult to prepare |  |  |
|  |  | Taste |  |  |
|  |  | Expensive |  |  |
|  |  | Constant income |  |  |
|  |  | Not available |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Demand for rice flour of consumers who buy rice flour** |  |  |  |
|  | **Bought** |  |  |  |
|  |  | Loose |  |  |
|  |  | Packed |  |  |
|  | **Reasons if packed** |  |  |  |
|  |  | Quality |  |  |
|  |  | Convenience |  |  |
|  |  | Availability |  |  |
|  |  | Other, please specify |  |  |
|  | **Reasons if loose** |  |  |  |
|  |  | Quality |  |  |
|  |  | Price |  |  |
|  |  | Blend to own taste |  |  |
|  |  | Availability |  |  |
|  |  | Other, please specify |  |  |
|  | **Buying same brand if packed** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Consumption experiences of rice of non-consumers** |  |  |  |
|  | **Rice** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Frequency** |  |  |  |
|  |  | Few times |  |  |
|  |  | Regularly |  |  |
|  | **Utilization and Preparation knowing** |  |  |  |
|  | Regional recipes rice based: please indicate any additional ingredient |  |  | *Additional ingredients:* |
|  |  | 1 |  |  |
|  |  | 2 |  |  |
|  |  | 3 |  |  |
|  |  | 4 |  |  |
|  |  | 5 |  |  |
|  |  | 6 |  |  |
|  |  | Etc… |  |  |
|  | **Structural Indicators/Attributes** | **Key questions** | **Source of Data / Information** | **COMMENTS** |
|  | **Awareness about the nutritional value of rice** |  |  |  |
|  | **Awareness of consumer** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Awareness non-consumers** |  |  |  |
|  |  | No |  |  |
|  |  | Yes |  |  |
|  | **Knowledge consumers** |  |  |  |
|  |  | Provides energy |  |  |
|  |  | Is nutritious |  |  |
|  |  | Increases appetite |  |  |
|  |  | Has proteins |  |  |
|  |  | Strengthening |  |  |
|  |  | Good for diabetic |  |  |
|  |  | Good for blood |  |  |
|  |  | Good for children |  |  |
|  |  | Other, please specify |  |  |
|  | **Knowledge non-consumers** |  |  |  |
|  |  | Provides energy |  |  |
|  |  | Is nutritious |  |  |
|  |  | Increases appetite |  |  |
|  |  | Has proteins |  |  |
|  |  | Strengthening |  |  |
|  |  | Good for diabetic |  |  |
|  |  | Good for blood |  |  |
|  |  | Good for children |  |  |
|  |  | Other, please specify |  |  |

1. FAO commodity list is tailored on commodity trees so that the primary crop and its derived products are traceable all along the value chain of agricultural production. [↑](#footnote-ref-1)
2. <http://www.ars.usda.gov/main/site_main.htm?modecode=12-35-45-00> [↑](#footnote-ref-2)
3. <http://www.fao.org/economic/the-statistics-division-ess/publications-studies/publications/nutritive-factors/en/> [↑](#footnote-ref-3)
4. <http://www.fao.org/docrep/t0395e/T0395E01.htm#Types%20of%20maize> [↑](#footnote-ref-4)
5. <http://www.fao.org/docrep/t0567e/T0567E01.htm> [↑](#footnote-ref-5)
6. <http://www.fao.org/docrep/t0567e/T0567E07.htm#Chapter%203%20-%20Grain%20structure,%20composition%20and%20consumers%27%20criteria%20for%20quality> [↑](#footnote-ref-6)
7. Juliano and Bechtel, 1985 [↑](#footnote-ref-7)
8. <http://www.fao.org/docrep/t0567e/T0567E04.htm#Chapter%202%20-%20Rice%20consumption%20and%20nutrition%20problems%20in%20riceconsu> [↑](#footnote-ref-8)
9. <http://www.fao.org/docrep/t0567e/T0567E05.htm#Nutritional%20problems%20in%20rice-consuming%20countries> [↑](#footnote-ref-9)
10. <http://www.fao.org/docrep/t0567e/T0567E0a.htm#Grain%20quality> [↑](#footnote-ref-10)
11. http://www.fao.org/docrep/006/y4751e/y4751e0o.htm [↑](#footnote-ref-11)
12. http://www.fao.org/docrep/t0567e/T0567E0h.htm#Chapter%205%20Rice%20post-harvest%20processing,%20parboiling%20and%20home%20preparation [↑](#footnote-ref-12)
13. http://www.knowledgebank.irri.org/step-by-step-production/postharvest/milling [↑](#footnote-ref-13)
14. http://www.fao.org/docrep/t0567e/T0567E0i.htm#Home%20preparation%20and%20cooking [↑](#footnote-ref-14)
15. http://www.fao.org/docrep/t0567e/T0567E0j.htm#Chapter%206%20Major%20processed%20rice%20products [↑](#footnote-ref-15)