RICE QUALITY

Bienvenido O. Juliano,
International Rice Research Institute, Philippines

Many problems encountered in processing and marketing of rice stem from the failure to identify clearly the desired final quality of the rice and its intended use. Rice scientists and technologists should choose methods of producing, drying, storing, processing, and marketing on the basis of the ultimate use and quality goals of the rice. The grading standards used for milled rice for direct consumption, for example, are inadequate for rices which require further processing, such as parboiling and puffing.

This paper examines the present methods of evaluating rice quality and makes a projection of future methods. The question of the use of by-products, though also important, is not discussed.

Market quality
Milled rice in the market place is usually graded and priced on the basis of grain size and shape, degree of milling, and grain translucency (absence of opaque portions). In the Asian market, the premium offered for whole grains or grains without discolouration is variable. Rice for local consumption usually contains many broken and discoloured grains, since little premium is offered for properly dried and milled rice. In addition, many processors lack the technical know-how to improve their rice processing methods.

Standards for grain size and shape differ among countries, although the Food and Agriculture Organization (FAO) has developed international standards. Translucency and colour are affected by environment and their assessment is largely subjective. Visual determination of degree of milling is not quantitative; neither is the dye-staining technique using methylene blue and Congo red. The X-M or solvent milling process results in higher yield of head rice, lower fat content, and whiter milled rice.

Although head rice yield reflects grain hardness, a rapid, reliable test for grain hardness of small samples does not exist. The Kiya type tester is insensitive and the Vickers and Smetar micro-hardness testers are too tedious to use routinely. Grinding methods such as those used for wheat, in which the fraction that passes through a fine mesh sieve after grinding for a given time is measured, also give an indication of grain hardness. Grain hardness, however, may not be related to
resistance to abrasive milling. Coarse grain varieties which have more aleurone layers usually require more pressure to mill to the same degree as slender, fine grain varieties in the McGill Mill. In addition, head rice yield is affected by environmental conditions such as moisture content at harvest, conditioning and drying after harvest, and by aging during storage.

Grain hardness may be related to the packing density of the starch and grain, as reflected in the gelatinization temperature of starch. Gelatinization temperature is the range of temperatures within which the starch starts to swell irreversibly in hot water with simultaneous loss of crystallinity. Final gelatinization temperature ranges from 56° to 79°C. It is classified as low (<69.5°C), intermediate (70°-74°C), and high (>74°C). The final gelatinization temperature of a variety may vary by as much as 10°C. Ambient temperature during grain development is positively correlated with gelatinization temperature differences within a variety. Gelatinization temperature correlates with the extent of disintegration of milled rice grain in the alkali test (Little, Hilder and Dawson 1958) and with the extent of amylolysis of starch during early germination (Kongseree 1971). The establishment of a more sensitive index of hardness should prove that gelatinization temperature is an index of grain hardness.

Cooking and eating qualities

Ironically, the criteria used for determining the price of rice usually are not related to eating quality and gloss of the resulting cooked rice. In tropical Asia rice is chiefly eaten as boiled milled rice. Varieties differ widely in the cooking and eating properties, depending on the ratio of the starch fractions, amylose and amylopectin. Amylose is the linear fraction of starch, and amylopectin, the branched fraction.

Amylose content is the chief influence on eating quality. It correlates negatively with taste panel scores for cohesiveness, tenderness, and gloss of cooked rice, and positively with water absorption and volume expansion of rice during cooking. Waxy or glutinous rice, whose starch is all amylopectin, expands the least during cooking. Thus, cooked waxy rice has the heaviest bulk density, but is very sticky, tender, moist and glossy. It retains these properties even after storage for a few hours. Steamed presoaked waxy rice is the staple food in Laos and in northern Thailand. Waxy rice is used for making desserts, rice cakes, and pudding. The flour may be used for thickening sauces and gravies because of its stable gel.

The amylose content of nonwaxy rice ranges from 7 to 34% of
Milled rice dry weight or 8 to 37% of starch. It may vary by as much as 6 percentage points within a variety. It may be classified as low (<20%), intermediate (20-25%), or high (>25%). No rice starch with more than 37% amylose has been found.

Although *japonica* varieties have low amylose, some have intermediate levels, particularly in cool-climate areas, such as Australia and South Korea. A low ambient temperature increases the amylose content of rice. Low-amylose rice is preferred in Japan because of its stickiness, tenderness, gloss, and taste. In many countries *japonica* rices with low amylose are used in brewing, baby foods, and breakfast cereals. They are more sensitive to overcooking than rices that have over 20% amylose. They disintegrate (edges and ends are split and frayed) when the cooked grain is soaked.

Most *indica* varieties have either intermediate or high amylose, although a few, such as Khao Dawk Mali from Thailand, have low amylose. High amylose varieties are common in tropical Asia but not in the United States and Australia. In the U.S.A., rices with about 24% amylose are preferred for parboiling and canning since, when cooked, their grain is stable even with prolonged soaking and reheating. Parboiled high-amylose rices are considered too firm for the canned soups in the United States. High amylose rices cook dry and fluffy, but harden readily on cooling. They appear dull, probably because of their high volume expansion during cooking. Because it has a harder texture, high amylose rice is flatter tasting than low-amylose rice.

The nature of rice flavour is not fully understood. Obata and Tanaka (1965) reported that the flavour of cooked rice contains a mixture of hydrogen sulfide, ammonia, carbon dioxide, and acetaldehyde vapours. Other volatile carbonyl compounds identified are isobutyraldehyde, propionaldehyde (or acetone), 3-caproaldehyde, 3-methylbutyraldehyde, methyl ethyl ketone and n-valeraldehyde (Kurasawa, Honma, Sato, Ueki, Shirai, Hayakawa and Morigami 1969; Yasumatsu, Moritaka and Wada, 1966).

Amylose is usually determined colourimetrically by the intensity of its blue-coloured complex with iodine. The standard method of Williams (1958) requires a 2-day gelatinization period and a pH meter. It employs an alkaline pH (9.8-10.0), where iodine is not stable. A simplified method was recently developed at the International Rice Research Institute and tried at 13 institutions in 11 countries. Milled rice is gelatinized in alkaline solution at 100°C and the solution is colourimetrically assayed with an Autoanalyzer or manually, with acetic acid for neutralization and 620 nm for absorbance readings to obtain results comparable to the Williams method. Other less accurate indexes are swelling number (Pelshenke and Hampel 1958) and
iodine blue values of starch at 77°C and 100°C. The values at 77°C are complicated by differences in degree of gelatinization, especially in samples that have a gelatinization temperature close to 77°C. The water-extractable amylose at 100°C corresponds to amylose content only for samples with less than 30% amylose (Juliano, Carraño and Vidal, 1968). Loss of dry matter in parboil-canning seems to be negatively correlated with amylose content. Amylose content correlates negatively with drop in viscosity during cooking at 94°C in the amylograph and positively with setback value (final viscosity after cooling to 50°C, minus peak viscosity). In addition, peak viscosity seems to be negatively correlated with amylose content but also decreased by protein content and increased during aging of the sample. At present, the amylograph does not provide additional information to that obtained from amylose content.

Another starch property, gelatinization temperature, directly affects the cooking time of milled rice. Although it is usually measured by the alkali test (spreading, clearing values), other tests which probably measure the same property are also often done simultaneously. They include heat alteration values at 62°C (Little and Hilder, 1960), water uptake at 77°C and 82°C (Halick and Kelly, 1959), expansion at 80°C (Pefai and Ahmad 1958), amylograph and cooking time (Halick, Beachell, Stansel and Kramer 1960; Ranghino 1966), and birefringence end-point temperature (polarizing microscope with hot stage).

In countries where rice varieties have similar amylose content, however, protein content may be the important quality factor. Among Spanish varieties (with 12-18% amylose), the preferred variety has higher protein and amylose content. Other countries where most varieties have high amylose are Malaysia, South Vietnam, and Ceylon. Some of the Vietnamese varieties are aromatic or scented. The aroma is volatile and does not last long in the grain during storage. The exact nature of the aroma has not been studied but varieties differ in the character of the aroma. Climatic factors have a marked effect on intensity of aroma. The preferred aroma may differ from region to region. In the trade, aromatic varieties, such as Basmati, are the exception because their aroma is transitional.

In Ceylon, the major differences among varieties are grain size and grain shape. Preferred 'samba' varieties have shorter grains than most Ceylonese varieties which have coarse and long grains.

Some rices, like Basmati, D25-4, and certain Iranian varieties show extreme elongation when presoaked grain is cooked. The nature of this property is not well understood. These samples tend to have low or intermediate gelatinization temperature, and an amylose content between 15 and 33%, but not all varieties
with this combination of properties show extreme elongation. Nevertheless, gelatinization temperature seems to be more important than amyllose content from our studies of different rices and of samples of Basmati grown in two locations differing in ambient temperatures during grain development.

**Storage changes and processed rice**

Storage of freshly harvested rice (whether rough, brown or milled) makes the starch and protein less soluble in water. It also causes harder grain, improved head rice yield, and higher water absorption and volume expansion during cooking. The nature of these changes are not fully understood. Amylograph peak viscosity values also increase after harvest. Since most of these changes occur within the first 3 to 4 months after harvest provided the storage temperature is above 15°C, rice breeders always age their samples prior to assay.

Because the range of eating quality requirements is wide, aging is considered beneficial in most tropical countries, but it lowers rice quality in Japan. In many tropical countries, rice is dry- or wet-heated to accelerate aging. Parboiling probably is used for this purpose. It is not clear what criteria are used in many countries for determining which samples need parboiling. Even fine varieties like Basmati are parboiled in some areas. Because of its improved hardness, parboiled rice tends to be relatively undermilled compared with raw rice under the same milling conditions.

Tests for raw rice are not always applicable to parboiled rice. The alkali test has little meaning for parboiled rice since the starch is already gelatinized. High amyllose (>25%) rices show a drastic drop in peak viscosity upon parboiling compared to low-amyllose rices (Raghavendra Rao and Juliano, 1970). Parboiled rice must be soaked before cooking or it will take longer to cook than raw rice. It also tends to expand more girthwise than lengthwise.

Processed rices, such as parboiled and precooked rices, present more storage problem than raw milled rice. They have gelatinized starch, so they have storage problems characteristic of precooked, dehydrated foods, and are more likely to develop odours. Cooked raw rice has a stronger flavour than precooked, processed rice. Stale odours characteristic of old, raw rices are due to the increase in volatile carbonyl compounds, including n-valeraldehyde and n-caproaldehyde, probably from the oxidation of polyunsaturated fatty acids, linoleic and linolenic, which decrease during storage (Yasumatsu, Moritaka and Wada, 1966).

A special problem of parboiled rice prepared by the traditional method of soaking at ambient temperature for several days is the high aflatoxin level. Since considerable amounts of micro-
organisms may be present in the soaking water which is used over and over again, the aflatoxin level in the milled rice may still be high, although it is concentrated in the bran.

**Nutritional value**
Rice is a principal source of calories and protein of Asians. It can contribute as much as 80% of calories and protein. Since protein intake in developing Asian countries is marginal, maintenance and improvement of protein content of the new varieties has an important impact on nutritional status in Asia. Protein is not a principal factor in eating quality, so protein must be improved without a corresponding decrease in yield. Although protein content can be increased together with yield, by a split application of nitrogenous fertilizer, the use of a variety with a genetically high protein content is more economical for the farmer, since fertilizer applied at close to flowering increases protein content of the grain but not yield. Parent varieties should have good amino acid balance to ensure good nutritive value in the resulting lines.

**Outlook**
With productivity increasing, consumers will be more discriminating about the eating quality and, probably, about the nutritional quality of the rice that they purchase. The breeders, the chemists, and the engineers will cooperate more closely in developing new varieties, for breeders no longer can rely on grain appearance to assess protein and amylose levels. Inheritance of amylose and protein should be studied to guide breeders in their breeding objectives since parents differing in these properties are being increasingly crossed in the breeding programme. The distinction between *indica* and *japonica* varieties will decrease in the future and amylose content may become a more important index of quality. Automation of analytical techniques will become necessary, especially in areas where two crops are grown in a year. Probably the size and shape of grain will be less related to eating quality. Already, IRRI has come up with a low amylose variety, IR24, that has a grain similar to that of high amylose variety, IR22.

Drying may integrate the parboiling effect, especially if mechanical harvesting is adopted widely in tropical Asia. Short-term, heat-exchange drying parboils the wet grain, thus improving the head rice yield and eating quality of freshly harvested grain. Such processes will minimize the aflatoxin problem during parboiling. Breakage will be less of a problem with the breeding of translucent lines. In countries where traditionally parboiled, yellow rice is consumed, the acceptance
of the non-coloured parboiled rice may be slow. Advances in the milling process, such as solvent milling will improve the standards for milled rice and rice by-products. Although gelatinization temperature, as indexed by the alkali test, is of little practical importance, it may eventually prove to be correlated with grain hardness.

The physicochemical changes that occur during rice aging will be elucidated when existing methods of characterizing changes in the fine structure of proteins and starch in the grain are further refined.

Although breeding for aromatic or scented varieties will continue, it is probable that flavour chemists will develop flavour and aroma additives that may be added to non-aromatic rices before cooking.

High protein rices (9-10%) will probably be produced in the late 1970s without sacrificing yield and protein quality. The inclusion of these rices as parents in national breeding programmes will necessitate chemical (Kjeldahl) analysis of the high yielding lines. Amino acid analysis and actual feeding experiments may have to be done on the promising lines.

For these reasons, cooperation between breeders, chemists, and engineers is indispensable for the continuing advance of knowledge and application of physicochemical properties of the grain as indexes of rice quality.