

RICE: CHEMISTRY
AND TECHNOLOGY

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CHAPTER 11

CRITERIA OF RICE QUALITY IN THE UNITED STATES

B. D. WEBB

National Rice Quality Laboratory

Agricultural Research Service

U.S. Department of Agriculture

*Texas A&M University Agricultural Research and Extension Center
Beaumont, Texas*

I. INTRODUCTION

The milling, cooking, processing, and nutritional qualities of rice plus appropriate standards for cleanliness, soundness, and purity are factors of great importance to the rice producing, processing, and consuming areas of the world, because these criteria establish the food and economic value of the rice grain. Throughout the world, rice is cooked, processed and consumed in hundreds of tremendously diverse ways. Therefore, it is little wonder that the qualities required of rice vary widely with different countries and that a multitude of methods were developed to assess these various qualities. This chapter does not try to detail all the qualities required and methods used to assess rice quality throughout the world. For more information on world rice qualities, the reader is referred to Chapter 12 of this monograph and to other international surveys of rices and methods used in different countries (Simpson et al, 1965; Juliano, 1982). This chapter discusses 1) the kinds and types of rice produced, processed, and used in the United States, 2) the qualities required in U.S. rices, and 3) the methods most used in quality assessment of U.S. rices.

II. TYPES OF RICE PRODUCED IN THE UNITED STATES

Rice produced in the United States is of three grain (kernel) types, long-, medium-, and short-grain (Fig. 1), and high grain quality is required of each if it is to succeed commercially (Adair et al 1973, Webb et al 1979). The major rice-producing areas of the United States are shown in Fig. 2. Arkansas, California, Louisiana, Mississippi, Missouri, and Texas are the leading rice-producing states (Table I). Florida also produces rice to a limited extent. These areas account for over 99% of U.S. production (Rice Millers Association, 1982).

Although the percentage amount of rice produced varies from year to year, the long-grain types usually account for over 60% of the total production, medium-grain types for about 30%, and short-grain types for the remainder (Holder and Grant, 1979).

Virtually all long-grain production is in the southern rice-growing area of Arkansas, Texas, Louisiana, and Mississippi. California produced its first commercial-scale long-grain crop on limited acreage in 1982 (Holder and Dorland, 1982) and is making a concerted effort to develop improved long-grain varieties adaptable for that area. Essentially all of California's production is in medium-grain types. In the southern area, Louisiana and Arkansas are the leading states producing medium-grain varieties. Except for a small acreage in the southern rice area, California is the exclusive producer of short-grain rice.

Rice is grown on less than 2% of U.S. cropland acreage but ranks sixth among the major field crops in production value (Rice Council, 1983a). Virtually all of the rice consumed in the United States is grown locally. Only insignificant quantities are imported (Rice Council, 1983b) and, for the most part, these are specialty rices that are not grown in the United States.

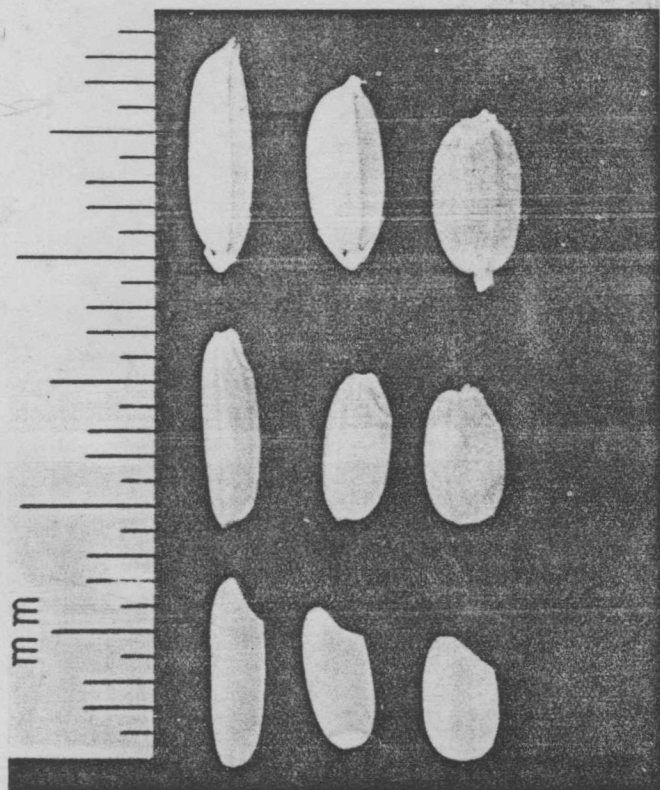


Fig. 1. Typical U.S. long-grain (left column), medium-grain (middle column), and short-grain (right column) types of rice. Top row, rough rice (paddy); middle row, brown rice; bottom row, milled head rice.

III. U.S. RICE DISTRIBUTION FOR DOMESTIC AND EXPORT FOOD USE

The amount of rice exported each year varies. Of the total U.S. rice crop, 50% or more is exported (Table II) to over 100 countries, and the remainder is used for domestic consumption (Rice Council, 1983b). All three grain types are exported, but long-grain rice is by far the leading and most preferred type for export as well as for domestic use. Although export figures fluctuate with world demand, raw (regular) milled rice accounted for about 60% of U.S. rice exports in recent years, with the remainder divided roughly equally between parboiled and brown rice (Holder and Dorland, 1982). European importers buy mostly brown and

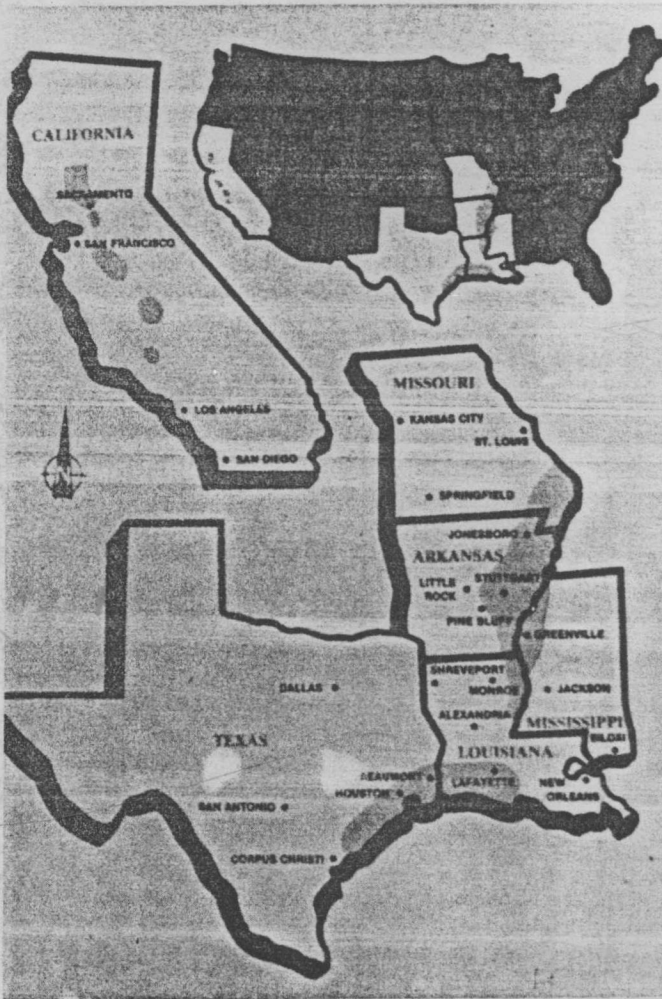


Fig. 2. Major U.S. rice-growing areas. (Courtesy Rice Council for Market Development, Houston, TX.)

TABLE I
U.S. Rice Production by Grain Type and State^a

Grain Type and State	Rough Rice Production				Hectares Harvested			
	1981		1982		1981		1982	
	1,000 t	Percent of Total	1,000 t	Percent of Total	1,000 ha	Percent of Total	1,000 ha	Percent of Total
Long-grain								
Arkansas	2,440.0	29.9	2,222.6	32.3	481.6	32.3	427.7	34.9
California	...	...	31.8	0.5	...	...	5.7	0.4
Florida	18.1	0.2	22.7	0.3	3.6	0.2	4.5	0.3
Louisiana	480.8	5.9	503.5	7.3	93.5	6.3	106.4	7.9
Mississippi	680.4	8.3	449.1	6.5	132.7	8.9	113.3	8.4
Missouri	140.6	1.7	131.5	1.9	30.8	2.1	28.3	2.1
Texas	1,106.8	13.6	938.9	13.6	218.5	14.7	179.7	13.3
Total	4,867.1	59.6	4,300.1	62.4	960.7	64.5	910.6	67.3
Medium-grain								
Arkansas	485.3	5.9	326.6	4.7	87.4	5.9	71.6	5.3
California	1,388.0	17.0	1,229.2	17.9	178.1	11.9	168.8	12.5
Florida	...	...	1.8	* ^b	0.4	*	0.4	*
Louisiana	757.5	9.3	557.9	8.1	169.6	11.4	129.9	9.6
Mississippi	4.5	0.1	...	...	6.5	0.4	...	...
Missouri	13.6	0.2	13.6	0.2	2.0	0.1	2.8	0.2
Texas	90.7	1.1	63.5	0.9	16.6	1.1	13.0	1.0
Total	2,739.6	33.6	2,192.6	31.8	460.6	30.8	386.5	28.6
Short-grain								
Arkansas	40.8	0.5	31.8	0.5	6.9	0.5	3.2	0.2
California	517.1	6.3	362.9	5.3	63.1	4.2	53.0	3.9
Missouri	...	...	0.9	*	...	...	...	...
Total	557.9	6.8	395.6	5.8	70.0	4.7	56.2	4.1
Totals	8,164.6	100	6,888.3	100	1,491.3	100	1,353.3	100

^a Adapted from Rice Millers Association (1982).

^b * = less than 0.05%

parboiled brown rice, which they then process by milling, packaging, and distributing (Rice Council, 1983b). The United States is a leading exporter of rice, generally accounting for 20–30% of the export trade, even though it produces less than 2% of the total world rice crop (Rice Council, 1983a).

The distribution and marketing structure for the U.S. rice industry is relatively simple (Holder and Grant, 1979). Geographically, the production of rice is more limited than that of most other field crops, and rice exchanges hands fewer times between the farmer and consumer. The normal movement (Fig. 3) of rice from farm to consumer includes drying and storage, milling and processing, and distribution.

IV. TYPES AND FORMS OF RICE CONSUMED IN THE UNITED STATES

Domestic consumption of rice continues to expand (Table III), and indications are that this strong upward trend will continue (Holder and Martella, 1980; Holder and Dorland, 1982). Among the three major outlets—direct food use, processed foods, and beer—rice used directly for food is, by far, the leader, accounting for about 60% of domestic consumption. Direct food use includes raw, parboiled, and precooked milled rice. Processed foods include cereals, packaged foods, baby foods, soups, etc.

U.S. per capita consumption for direct food use averaged 3.6 kg in 1980–1981, ranging from about 1.4 kg in the East South Central area to almost 6.4 kg in the

TABLE II
United States Rice Distribution by Grain Type for Domestic
and Export Food Use, 1978–1979 and 1980–1981^{a,b}

	Milled Rice Basis			
	1978–1979		1980–1981	
	Percent	1,000 t	Percent	1,000 t
Domestic				
Long-grain	16.4	554.1	15.1	730.7
Medium-grain	6.4	216.5	5.9	283.5
Short-grain	1.2	40.0	0.6	30.6
Brokens	12.1	408.5	7.0	340.7
Total	36.1	1,219.1	28.6	1,385.5
Export				
Long-grain	49.3	1,664.7	45.0	2,172.7
Medium-grain	12.1	408.2	22.8	1,102.2
Short-grain	2.5	86.2	3.6	172.4
Total	63.9	2,159.1	71.4	3,447.3
Totals	100	3,378.2	100	4,832.8

^aBased on survey data accounting for approximately 88% of milled rice shipments for domestic food use in the marketing year 1980–1981, beginning August 1, and for approximately 95% of milled shipments for the 1978–1979 marketing year. Exports are based on 48 of 53 mills reporting distribution data in 1980–1981 and 36 of 45 mills in 1978–1979.

^bAdapted from Holder and Dorland (1982) and Holder and Martella (1980).

Pacific region (Fig. 4).¹ From 1975 to 1981, per capita consumption of rice increased 70% (Holder and Dorland, 1982; Rice Council, 1983b). More recent projections indicate that per capita consumption for direct food use and processed foods is over 4.0 kg, and if rice for brewing is included, the average per capita consumption approaches 6.4 kg.

A detailed breakdown of the types and forms of rice used domestically, along with the quantity and percentage of each, are given in Table IV. Traditionally, long-grain raw milled rice is by far the most popular type and form of home-boiled table rice consumed in the United States. Parboilers and manufacturers of

¹ Factors to convert kilograms to pounds; metric tons to pounds; hectares to acres; and kilograms per hectare to pounds per acre are 2.2046, 2204.6, 2.471, and 0.8922, respectively.

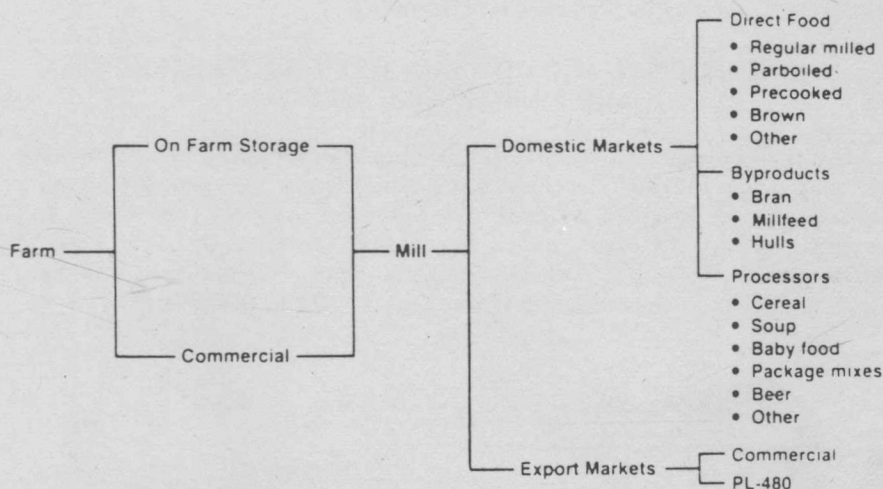


Fig. 3. Market channels for U.S. rice. Source: USDA (Holder and Grant, 1979).

TABLE III
Rice Consumption Trends in the United States for Selected Years^a

Year ^b	Rice Consumed (Milled Basis)						Total
	Direct Food Use ^c		Processed Food Use ^d		Beer Use		
	1,000		1,000		1,000		
	t	Percent	t	Percent	t	Percent	
1955-1956	367.4	63.3	68.0	11.7	145.2	25.0	580.6
1966-1967	503.5	64.5	136.1	17.4	140.6	18.0	780.2
1974-1975	571.5	59.4	113.4	11.8	276.7	28.8	961.6
1975-1976	589.7	63.7	127.0	13.7	208.7	22.5	925.3
1978-1979	689.5	56.1	167.8	13.7	371.9	30.3	1,229.2
1980-1981	852.8	60.8	204.1	14.6	349.3	24.9	1,401.6

^a Adapted from Holder and Dorland (1982).

^b Marketing year beginning August 1.

^c Includes regular milled, parboiled, precooked, and brown rice.

^d Includes cereals, package mixes, soups, baby foods, etc.

precooked rice use predominantly long-grain types, whereas cereal manufacturers use mostly the medium- and short-grain types. Long-grain rice accounts for about two thirds of the rice used in package mixes and for the major amount in soups and brown rice products. The beer industry uses mostly broken rice, but whole-grain milled rice is purchased when broken are in short supply (Holder and Dorland, 1982). Some breweries prefer to use mostly short-, and medium-grain broken, whereas others use broken from all grain types.

The use of rice in making beer is one of the fastest growing segments of the domestic rice market. Breweries in the United States increased the use of milled rice from 272 to 435 thousand tonnes from 1975 to 1983 (Anonymous, 1984). Rice has long been considered a superior ingredient in beer brewing, but because it costs more than corn, most breweries have used corn. More and more breweries are now associating the use of rice with increased beer sales and, as a result, the use of rice by breweries is accelerating.

V. TRADITIONAL AND COMMON METHODS OF COOKING AND PREPARING U.S. RICE

Most rice packages have easy-to-follow directions for preparing high-quality rice, but when package directions are not available, the same high-quality product can be obtained by using the following method(s) published and recommended by the Rice Council for Market Development (Rice Council 1983a, 1983b), P.O. Box 740121, Houston, Texas 77274, USA. The Rice Council's (1983a) 1-2-1 method provides an easy way to remember the correct

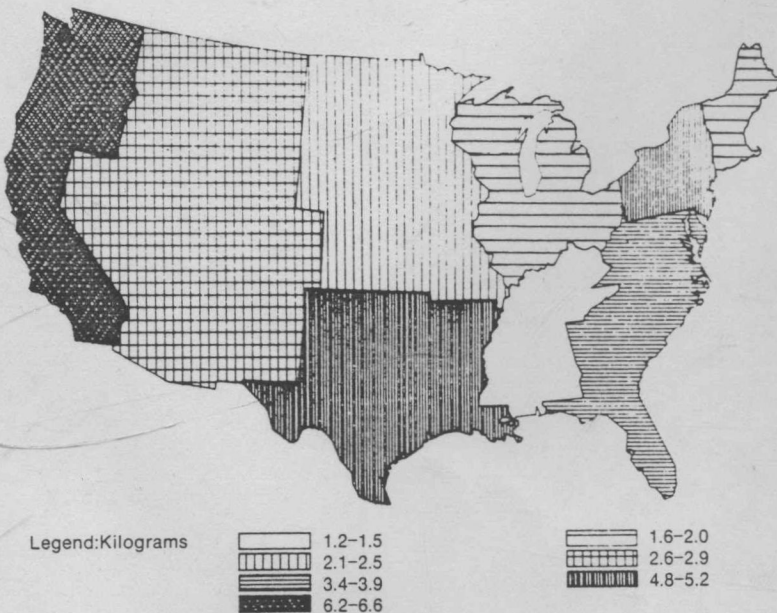


Fig. 4. Per capita consumption of rice in the United States by major U.S. regions, 1980-1981. Source: USDA (Holder and Dorland, 1982).

TABLE IV
Types and Forms of Rice Consumed in the United States,^a 1978-1979 and 1980-1981^b

Rice Type and Form	Year	Long-Grain		Medium-Grain		Short-Grain		Broken ^c		Total	
		Percent	1,000 t	Percent	1,000 t	Percent	1,000 t	Percent	1,000 t	Percent	1,000 t
Regular milled white	1978-1979	31.9	388.3	12.9	157.2	0.8	9.4	...	...	45.5	554.9
	1980-1981	34.9	483.7	13.2	182.8	0.9	12.9	...	...	49.0	679.4
Parboiled	1978-1979	6.3	76.6	*	0.1	0	0	...	...	6.3	76.7
	1980-1981	6.5	89.6	*	0.6	0	0	...	...	6.5	90.2
Precooked	1978-1979	3.1	37.3	0	0	0	0	...	...	3.1	37.3
	1980-1981	3.4	46.7	0	0	0	0	...	...	3.4	46.7
Brown	1978-1979	0.3	3.7	0.4	4.7	0.3	3.2	...	...	1.0	11.6
	1980-1981	0.7	9.9	0.3	4.2	0.2	2.9	...	...	1.2	17.0
Cereals	1978-1979	0	0	3.8	46.0	2.2	27.1	1.8	21.7	7.8	94.8
	1980-1981	1.1	14.6	5.0	69.8	1.1	14.7	1.3	18.3	8.5	117.4
Package mixes	1978-1979	3.3	40.5	0.7	8.5	*	0.2	*	0.5	4.1	49.7
	1980-1981	3.0	41.4	1.5	20.6	0	0	...	...	4.5	62.0
Soups	1978-1979	0.6	7.1	0	0	0	0	...	...	0.6	7.1
	1980-1981	0.5	6.7	0	0	0	0	...	...	0.5	6.7
Baby foods	1978-1979	0	0	0	0	0	0	0.6	6.9	0.6	6.9
	1980-1981	0	0	0	0	0	0	0.4	6.0	0.4	6.0
Beer	1978-1979	0	0	0	0	0	0	30.4	370.1	30.4	370.1
	1980-1981	2.8	38.3	0.2	2.6	0	0	22.1	306.9	25.1	347.8
Other ^d	1978-1979	0.1	0.6	0	0	0	0	0.8	9.3	0.8	9.9
	1980-1981	0.2	2.9	0	0	0	0	0.7	9.5	0.9	12.4
Totals	1978-1979	45.5	554.1	17.8	216.5	3.3	39.9	33.5	408.5		1,219.0
Totals	1980-1981	53.1	733.8	20.2	280.6	2.2	30.5	24.5	340.7		1,385.6

^a Based on survey data accounting for approximately 88% of milled rice shipments for domestic food use in marketing year 1980-1981, beginning August 1, and for approximately 95% of milled rice shipments for the 1978-1979 marketing year.

^b Adapted from Holder and Dorland (1982) and Holder and Martella (1980).

^c * = less than 0.05%.

^d Includes rice flour, candies, pet foods, etc.

proportions² of liquid to rice: 1 cup (240 ml) regular milled rice, 2 cups (480 ml) liquid (water, broth, consomme, juice), 1 teaspoon (5 ml) salt, and 1 tablespoon (15 ml) butter or margarine (optional ingredient). For drier, fluffier rice, the liquid may be decreased by 2-4 tablespoons (30-60 ml).

The amount of liquid and the cooking time vary slightly for different rices. The Rice Council's (1983a, 1983b) recommendations for the various grain types and forms are shown in Table V.

For the Rice Council's (1983a) top-of-the-range cooking method:

combine rice, liquid, salt, and butter or margarine in a 2 to 3-quart (1.9 to 2.85 l) saucepan. Heat to boiling, stir once or twice, and lower heat to simmer. Cover with a tight-fitting lid and cook 15 min (20 to 25 min for parboiled rice; 45 min for brown rice). If rice is not quite tender or liquid is not absorbed, replace lid and cook 2 to 4 min longer.

In addition to cooking rice on top of the range, one can prepare it in a conventional or microwave oven and in automatic or nonautomatic rice cookers. The Rice Council's (1983b) oven method is an efficient use of energy when other foods are roasting.

Use boiling liquid. Combine ingredients in a baking dish or pan and stir. Cover tightly and bake at 350° F (176.7° C) for 25 to 30 min, (30 to 40 min for parboiled; 1 hr for brown rice).

The Rice Council's (1983b) microwave method saves energy and cleanup time.

Use 2 cups (480 ml) liquid for regular-milled, parboiled, and brown rice. Combine all ingredients in a microwave proof baking dish. Cover and cook on HIGH (maximum power) 5 min or until boiling. Reduce setting to 50% power and cook 15 min (for brown rice, reduce setting to 30% power and cook 45 min). Fluff with a fork.

²Factors to convert liters to quarts; milliliters to cups; milliliters to tablespoons; and milliliters to teaspoons are 0.95, 240, 15, and 5, respectively.

TABLE V
Recommended Cooking Procedures^a

Uncooked Rice (1 cup [240 ml])	Liquid (cups [ml])	Cooking Time (min)	Yield of Cooked Rice (cups [ml])
Regular-milled white			
Long-grain	1½-2 [420-480]	15	3 [720]
Medium- or short-grain	1½ [360]	15	3 [720]
Brown	2-2½ [480-600]	45-50	3-4 [720-960]
Parboiled	2-2½ [480-600]	20-25	3-4 [720-960]
Precooked	Follow package directions.		
Flavored or seasoned mixes	Follow package directions.		

^aAdapted from Rice Council (1983a, 1983b).

Several reliable automatic and nonautomatic rice cookers are available for use in the Rice Council's (1983a) rice cooker method.

Care should be taken to follow individual manufacturer's directions. In general, however, all ingredients are combined using $\frac{1}{4}$ to $\frac{1}{2}$ cup (60 to 120 ml) less liquid than the top-of-the-range method.

When rice is cooked in milk, it is often cooked over boiling water as in the Rice Council's (1983b) double boiler method.

Place 1 cup (240 ml) uncooked, regular milled rice in the top of a double boiler with $3\frac{1}{2}$ cups (840 ml) milk and 1 teaspoon (5 ml) salt. Heat to boiling, and place over boiling water and cook, covered, for 40 min, or until the rice is tender and the milk is absorbed.

Different cooking mediums affect rice cooking behavior in various ways (Rice Council, 1983b).

ACID mediums such as tomato, fruit juice, and wine have a tendency to make the rice grain cook firmer and to lengthen the cooking time. It is recommended that these juices be diluted 1 part water to 1 part juice. MILK has a tendency to lengthen the cooking time. FAT is often added to the cooking liquid to help keep the grains separate. When raw rice grains are sautéed in fat, the fat coats the rice to keep the grains more separate and the hot fat also has a tendency to break down the starch on the surface of the rice. This results in a final cooked product that has a slightly mealy texture and splayed ends on the grains. SUGAR in the cooking liquid, especially in high concentrations, will result in firmer rice grains. Using a U.S. medium or short grain rice will reduce the firming effect of the sugar.

Cooked rice can be kept refrigerated for six to seven days or frozen for up to four months. The Rice Council (1983a, 1983b) recommends covering the rice tightly so the grains won't dry out or take on any "refrigerator" flavors. Refrigeration does have a tendency to make the grains firmer, but reheating the rice with a little liquid will restore the texture. For reheating rice, the Rice Council (1983a) recommends adding

2 tablespoons (30 ml) liquid for each cup (240 ml) cooked rice. Cover and heat 4 to 5 min on top of range or in oven. In a microwave oven, cover and cook on HIGH (maximum power) about 1 min per cup (240 ml) of cooked rice.

No hard and fast rules determine which type or form of rice to use in any particular recipe (Rice Council, 1983b). According to this report, the choice is largely a matter of personal preference. Medium-grain rice would be a good choice for making creamy dishes, such as risotto, molds, desserts, or croquettes. Long-grain types would be the choice for the separate distinct grains desirable in pilaf. Short grain rice works well in sushi.

VI. VARIETIES OF RICE IN THE UNITED STATES

The U.S. rice industry is highly diverse, complex, and innovative in the areas of rice production, domestic consumption, and export programs and the qualities needed for each. Rice varieties of each grain type and quality must be available to

meet the requirements of the various and continually expanding market channels, and high grain quality is an absolute prerequisite for all new U.S. rice varieties.

Over 99% of the U.S. rice crop is produced from rice varieties (*Oryza sativa* L.) developed and released by the cooperative rice research centers and experiment stations located at Stuttgart, Arkansas; Biggs, California; Crowley, Louisiana; and Beaumont, Texas. For many years, these locations have had active breeding programs conducted cooperatively by the four state agricultural experiment stations, the U.S. Department of Agriculture, and various state and local producer organizations (Adair et al, 1973; Webb et al, 1979; Webb, 1980).

Although tens of thousands of rice varieties exist worldwide, only a few (usually less than a dozen) different varieties are grown commercially in the United States in any one crop year. Generally these consist of four or five long-grain, four or five medium-grain, and one or two short-grain varieties, which are continually being replaced by new, improved varieties developed in the cooperative breeding programs.

Previously, rice breeding programs placed most emphasis on grain yield, grain type and appearance, milling yield, plant type, nitrogen responsiveness, and resistance to diseases and insects. Now, high priority is given to cooking and processing qualities in the development of new varieties, and these attributes are assessed at the USDA National Rice Quality Laboratory in Beaumont, Texas (Adair et al, 1973; Webb et al, 1979; Webb, 1980).

With but few exceptions, the grains of all rice varieties in commercial production in the United States are described as straw-hulled, nonpigmented pericarp, translucent, nonscented, nonwaxy (common) types containing varying ratios of amylose and amylopectin starch and possessing a mild bland taste and flavor. One exception is the limited production of waxy (glutinous) short-grain rice. This rice, also called "sweet rice," is characterized by an opaque endosperm containing virtually all amylopectin-type starch. When cooked, it tends to lose its shape and to be very glutinous. Waxy rice is produced primarily for specialty products, for specific ethnic-group uses, and in several commercial product formulations, including sauces, gravies, salad dressing, desserts, pizza shells, and batter dips for fried chicken.

Another exception is a scented (aromatic) long-grain rice produced on small acreages as a specialty product. This rice gives off an aroma similar to that of roasted popcorn or nuts and has a flavorful, nutty taste similar to that of the much-sought-after Basmati class of varieties in Pakistan and India. Its translucent grain contains relatively high levels of amylose-type starch. A major constituent responsible for the unique flavor of this type of rice was recently identified as 2-acetyl-1-pyrroline, which is present in the volatile oil fraction of cooked rice (Buttery et al, 1982, 1983a, 1983b).

A third exception, also produced in limited amounts for localized specialty markets in the United States, is the so-called "Toro" type of rice. This rice has the grain size and shape of U.S. long-grains but possesses the cooking and eating behavior of U.S. short- and medium-grain types. Toro quality rice is used by a small, localized segment of the population that prefers the clingy cooked texture of U.S. short- and medium-grain rice in a long-grain type.

More recently, a long-grain rice with superior processability, referred to as "Newrex" type quality, was developed (Bollich et al, 1980) to satisfy the rice

industry's need for a drier and fluffier table rice with improved processability for manufacturing into canned, quick-cooking, and frozen types of rice products. "Newrex" type quality represents the first major improvement in U.S. long-grain quality and is the forerunner of rices of superior processability.

The genetic, agronomic, disease, and cultural characteristics of U.S. rice varieties are not considered in this chapter. The interested reader should consult more detailed accounts (Adair et al. 1973; Hodges et al. 1979; Bollich et al. 1981) and the original papers for a fuller description of these attributes of U.S. rice.

VII. CONCEPTS OF RICE QUALITY IN THE UNITED STATES

The many diverse uses of U.S. rice, both domestically and for export, require that its quality be evaluated according to its suitability for specific end-uses for particular consumers. Quality determination is based on a combination of subjective and objective factors; how these are ranked in importance in evaluating rice quality depends largely upon end-use. For example, a homemaker shopping for table rice might prefer a long-grain rice that cooks dry and fluffy and would rank these factors of foremost importance, whereas a cereal manufacturer of puffed rice would probably rank a short-plump grain of most importance and would not be concerned about whether it was moist and sticky if cooked as table rice (Holder and Grant, 1979).

Whether a rice is satisfactory for an intended use is principally determined by quality testing. Most rice, unlike many other cereal grains, is processed and consumed in whole-grain form, and the physical properties of the intact grain, such as size, shape, uniformity, and general appearance, are of foremost importance in evaluating rice quality. Also because nearly all the U.S. rice crop is milled to a relatively high degree, its quality is closely related to the characteristics of the milled endosperm (Webb and Stermer, 1972).

Rice quality is influenced by some characteristics under genetic control and by some independent of genetic control such as cleanliness, soundness, and purity. These latter characteristics are principally a function of handling, storage, and distribution and are described in the U.S. Standards for Rice (USDA, 1983) and in the Rice Inspection Handbook (USDA, 1982).

The genetic makeup of the grain and the environment in which the plant is grown are major factors influencing quality in rice. Modern breeding programs strive to refine and improve the inherent characteristics of rice that influence quality to obtain the attributes desired by the U.S. rice industry. In the United States, new rice varieties are developed through intensive breeding and genetic selection of all important quality characteristics (Webb et al. 1979).

Marked differences in rice quality also exist because of environmental and cultural practices during growth. In some instances, differences due to these factors may be as great or greater than inherent factors. Factors influencing rice quality that are independent of inherent, cultural, and environmental conditions include those associated with handling, storage, and the presence of foreign material. For example, rice that has been stored for long periods, or stored under unfavorable conditions for shorter times, may have lower yields of processed products and contain various degrees of objectionable odors and flavors, which would decrease its suitability for human consumption. On the other hand, a short period of maturation after harvest (aging), under safe storage conditions, is considered desirable by many users because it permits important changes in

enzymatic activity to occur.

Hence, rice quality may be divided into four broad categories: 1) milling quality; 2) cooking, eating, and processing quality; 3) nutritive quality; and 4) qualities associated with cleanliness, soundness, and purity. All are important, collectively, in assessing the suitability of rice for a particular use. The nutritional quality of rice is important to all areas of rice use, and the many phases of nutritive quality are covered in appropriate chapters in this monograph and in other excellent reviews (Houston and Kohler, 1970; Adams, 1975; Eggum, 1979; Kennedy, 1980).

A wealth of information has also been published on rice quality and testing, quality requirements for rice processing and utilization, and related areas for U.S. as well as world rices. Much of this information is contained in five books or handbooks, each of which lists numerous original references of significance to the interested reader. These are: *Rice: Chemistry and Technology* (Houston, 1972); *Nutritive Value of American Foods. Agriculture Handbook No. 456* (USDA, 1975); *Proceedings of Workshop in Chemical Aspects of Rice Grain Quality* (IRRI, 1979); *Rice: Production and Utilization* (Luh, 1980); and *Handbook of Processing and Utilization in Agriculture, Vol. II: Part I, Plant Products* (Wolff, 1982).

VIII. INTERRELATIONSHIP OF VARIETY, GRAIN TYPE, AND QUALITY IN THE UNITED STATES

Rice varieties in the United States are also classed for marketing purposes as long-, medium-, and short-grain (Fig. 1) types. Historically, and now through planned breeding, each grain type is associated with specific milling, cooking, and processing characteristics. Grains of typical long-grain varieties cook dry, fluffy, and separate when boiled or steamed and are preferred for use in such prepared products as parboiled rice, quick-cooking rice, canned rice, canned soups, dry soup mixes, frozen dishes, and other convenience-type rice-containing foods. Typical short- and medium-grain types, on the other hand, cook moist, chewy, and clingy and are preferred for such products as dry breakfast cereals and baby foods and for brewing uses. All three grain types and their qualities are in rather widespread demand by both the domestic and foreign trades. Most consumers in the United States prefer the dry, fluffy, and separate texture of the long-grain types, although some prefer the more moist and clingy (sticky) texture of the short- and medium-grain types.

Processors and reproprocessors of rice need a variety of grain types and textural qualities for the various kinds of prepared products (Luh and Bhumiratana, 1980; Luh and Liu, 1980a, 1980b; Luh and Mickus, 1980; Luh et al, 1980). An ever-increasing amount of the domestic rice crop is processed into products such as parboiled and quick-cooking rice, dry cereals, canned products, packaged mixes, and baby foods. Rice flour is preferred for dietetic formulations and in nonallergenic baking. Long-grain rice types are preferred in some of these products and medium- and short-grain types in others.

The association of grain type with specific cooking and processing behavior occurs primarily in the United States and is a result of planned breeding (Adair et al, 1973; Webb et al, 1979). Throughout the world, short- and medium-grain varieties exist with the cooking, eating, and processing characteristics of U.S.

long-grain types and long-grain varieties exist with the properties of U.S. short- and medium-grain types. Varieties of grain type possessing nontypical cooking and processing qualities pose serious identity, drying, handling, storage, distribution, blending, and end-use problems to the U.S. rice industry. Thus, rice producers, processors, and distributors of specialty rices such as the waxy, aromatic, and Toro types are required to be extremely cautious in keeping these types separate from the traditional U.S. long-, medium-, and short-grain rices in all stages of the rice production, processing, and distribution cycle.

IX. COMPONENTS OF RICE QUALITY

Rice quality factors that are important, collectively, in assessing the suitability of rice for its various end-uses and important to the U.S. rice industry in producing, processing, and utilizing the U.S. rice crop for domestic consumption and for export markets include those summarized in Fig. 5.

A. Hull and Bran (Pericarp) Color

Hull color and anthocyanin pigmentation in the apiculus affect color quality aspects of parboiled rice. Varieties produced in the United States are either light- (straw-colored) or dark- (gold) hulled types (Fig. 6). In the manufacture of parboiled rice in the United States, light hulls are usually preferred because they produce a lighter finished parboiled product than do dark-hulled varieties processed under similar conditions (Gariboldi, 1974). Most users prefer a lighter parboiled rice, although some export markets prefer a darker parboiled product,

- Hull and bran color
- Grain characteristics
 - Size, shape, weight, and uniformity
 - Translucency
 - Chalkiness
- Milling quality
 - Whole-grain (head-rice) yield
 - Total milled rice yield
 - Milling uniformity
- Cooking and processing quality indexes
 - Amylose content
 - Alkali spreading value
 - Protein content
 - Gelatinization temperature and type
 - Water uptake capacity
 - Parboil-canning stability
 - Brewing cookability of rice with malt diastase
- Additional grading factors included in U.S. Standards for Rice
 - Moisture content
 - Test weight
 - Degree of milling
 - Color
 - Dockage
 - Damaged grains and heat-damaged grains
 - Odors
 - Red rice

Fig. 5. Components of rice quality in the United States.

for which a dark-hulled variety may be preferred.

Bran color, shown also in Fig. 6, affects parboiling in that undesirable dark, nonuniform colors from damaged and discolored bran can be imparted to the parboiled grain during the parboiling process. Bran color is also a factor in the milling of both raw and parboiled rices, where increased milling pressure (most often resulting in lower milling yields) is required to remove or minimize the dark areas. For U.S. varieties, the bran is characteristically a uniform light brown color. Breeders select for both hull color and bran color subjectively by close visual examination, beginning in early generation lines and continuing in each following generation until the variety breeds true.

B. Grain Size, Shape, Weight, and Uniformity

Since rice in the United States is produced and marketed according to grain size and shape, the physical dimensions, weight, and uniformity of rice grains are of vital interest to those involved in the many facets of the rice industry (Kramer, 1951). These physical properties are primary quality factors in the breeding, handling, drying, cleaning, marketing, and processing of end-use products. Varieties of each of the three grain types must conform to rather narrow limits of size and shape specification for their respective grain type. Average values and ranges of values for grain size, shape, and weight of rough, brown, and milled forms of traditional U.S. long-, medium-, and short-grain types are shown in Table VI.

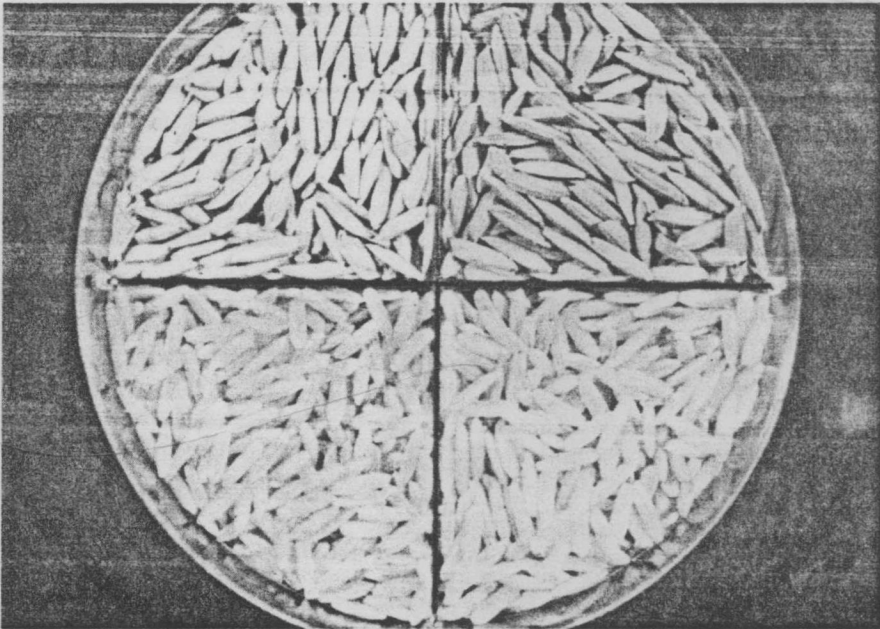


Fig. 6. Hull and bran types of U.S. rices. Top left, light (straw) hulls; top right, dark (gold) hulls; bottom L and R, both light (nonpigmented) bran.

Grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release in commercial production. If the variety does not conform to recognized standards for grain size, shape, weight, and uniformity, it is not considered for release. In early developmental stages, close visual examination of the grain is made to determine that its configuration conforms to that of other commercially acceptable varieties of the same grain type.

Although grain type can be visually classified subjectively, more exact measurements are needed for objective classification and for comparison of varieties. Rice grains may be objectively classified into grain-type categories based upon three physical quantities: length, shape, and weight. Definitions for each dimension are described by Adair et al (1973). Length is a measure of the rough-, brown-, or milled-rice grain in its greatest dimension. Shape is determined by a ratio of two of the three dimensions—length, width, and thickness. The most used and meaningful of these is the length-width ratio. Finally, the grain weight (size) is determined by determining the mean of the weight of a 1,000-grain representative sample. Uniformity of grain size and shape is calculated by determining the coefficient of variation for each dimension of the sample. Size and shape classes used as guides in U.S. rice breeding programs for brown-rice grains are shown in Table VII.

TABLE VI
Range of Average Measurements^a of Grain Size and Shape Among
Typical U.S. Commercial Long-, Medium-, and Short-Grain Types^b

Grain Type	Grain Form	Average Length (mm)	Average Width (mm)	Average Length/Width Ratio	Average Thickness (mm)	Average 1,000-grain Weight (gm)
Long	Milled ^c	6.7–7.0	1.9–2.0	3.4:1–3.6:1	1.5–1.7	15–18
	Brown ^d	7.0–7.5	2.0–2.1	3.4:1–3.6:1	1.6–1.8	16–20
	Rough ^e	8.9–9.6	2.3–2.5	3.8:1–3.9:1	1.8–1.9	21–24
Medium	Milled	5.5–5.8	2.4–2.7	2.1:1–2.3:1	1.7–1.8	17–21
	Brown	5.9–6.1	2.5–2.8	2.2:1–2.4:1	1.8–2.0	18–22
	Rough	7.9–8.2	3.0–3.2	2.5:1–2.6:1	1.9–2.1	23–25
Short	Milled	5.2–5.4	2.7–3.1	1.7:1–2.0:1	1.9–2.0	20–23
	Brown	5.4–5.5	2.8–3.0	1.8:1–2.0:1	2.0–2.1	22–24
	Rough	7.4–7.5	3.1–3.6	2.1:1–2.4:1	2.1–2.3	26–30

^aOf fully developed mature kernels of typical varieties within each grain type.

^bSource: Webb (1980); used by permission.

^cWhole milled grains with hull, bran, and germ removed.

^dGrain with hull removed.

^eUnhulled grain (paddy).

TABLE VII
Size and Shape Classes Used As Guides in U.S. Breeding Programs^a

Grain Type	Brown Rice Grain		
	Length (mm)	Length-Width Ratio	Weight (mg)
Long	6.61–7.5	3.1 and over	15–20
Medium	5.51–6.6	2.1–3	17–24
Short	up to 5.5	2.0 and less	20–24

^aData from Adair et al (1973).