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Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief, and the Bureau of Chemistry, Carl L. Alsberg, Chief

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THE MILLING OF RICE AND ITS MECHANICAL AND CHEMICAL EFFECT UPON THE GRAIN.

By F. B. WISE, *Assistant, Office of Grain Standardization*, and A. W. BROOMELL, *Assistant Chemist, Food-Control Laboratory.*

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INTRODUCTION.

GEOGRAPHICAL DISTRIBUTION AND VALUE OF THE RICE CROP.

From early colonial days until the Civil War, rice was an important crop in the coastal plains of South Carolina and the adjacent States. During the past quarter of a century, however, the production of rice in Louisiana, eastern Texas, and Arkansas has risen to a preeminent position. Of the 1913 rice crop of the United States, valued on the farm at $22,090,000, approximately 45 per cent was grown in Louisiana, 38 per cent in Texas, and 15 per cent in Arkansas. The relative importance of the rice-producing areas of the United States is shown in figure 1. With the opening of the great southern prairies of Louisiana and Texas for rice culture and its more recent development in Arkansas, the production of rice in the United States has increased enormously. Not less striking, however, have been the improvements in the methods of planting, harvesting, thrashing, and milling.

Much has been written about the new agricultural schemes for producing the rice crop, but very little literature is available on the milling processes now in use. It is the object of this paper to describe

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briefly these processes and the machinery employed, and to consider each operation in the light of its effect on the chemical and mechanical qualities of the finished products. It is hoped that in so doing it may be possible to correct some of the popular misunderstandings of the various grades and finishes of rice now found on the market.

STRUCTURE OF THE RICE GRAIN.

A brief description of the physical and microscopic structure of the rice grain is of such value in understanding the milling processes that it is presented here. Prior to 1914 about half of the rice grown in the United States was of the Honduras type and nearly all the remain-

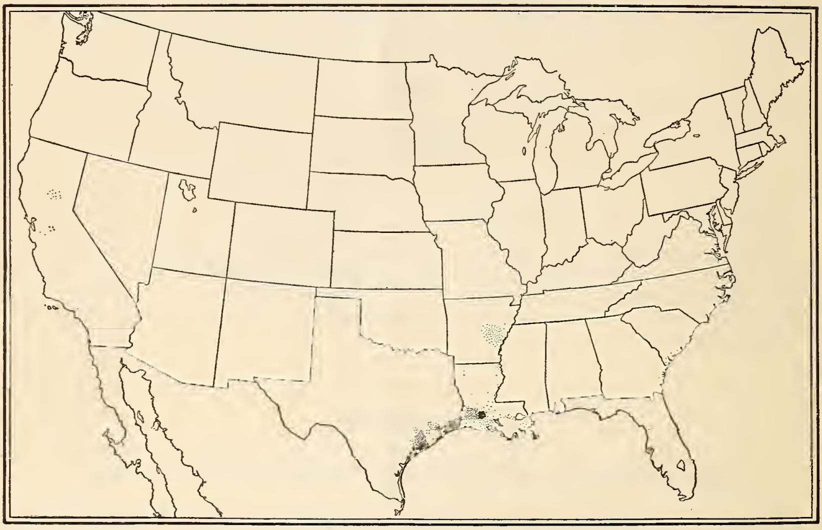

FIG. 1.—Outline map of the United States, showing the relative importance of various rice-producing areas in 1914; each dot represents 50,000 bushels.

der was of the Japan type, each deriving its name from the country from which it was originally imported.[1] The grain of the Honduras type of rice is long and slender, that of the Japan type distinctly smaller and more nearly round, but from the viewpoint of the structure of the grain the two are virtually the same.

The rice grain as it leaves the farm thrasher and enters the mill is covered with a hard, siliceous hull, or palet, which is loosely attached to the edible grain within. The germ, or embryo, is distinctly visible near the base of the hulled grain. Directly beneath the hull, but separate from it and firmly attached to the starchy body of the grain itself, is a light-brown bran coat. A careful study of this coat with the microscope reveals seven types of cells arranged in layers and enveloping the starchy interior of the grain. Figure

[1] In 1914 the rice known commercially as "Blue Rose" was first widely grown throughout the rice belt. In shape and size the grains of Blue Rose rice are intermediate between those of the Honduras and the Japan types.

2 represents a cross section of a rice grain, and shows, in addition to the hull, the disposition of the seven layers. On the outside of the hulled grain lie, in order, the epicarp, mesocarp, cross cells, and tube cells. These four are frequently grouped together and called the pericarp. Beneath this are the spermoderm, perisperm, and aleurone layers.

During the process of milling, there are removed, in addition to the hull, most of the outer six coats and a portion of the seventh, leaving only the starchy part of the endosperm surrounded by a portion of the aleurone layer. Since the aleurone cells are rich in

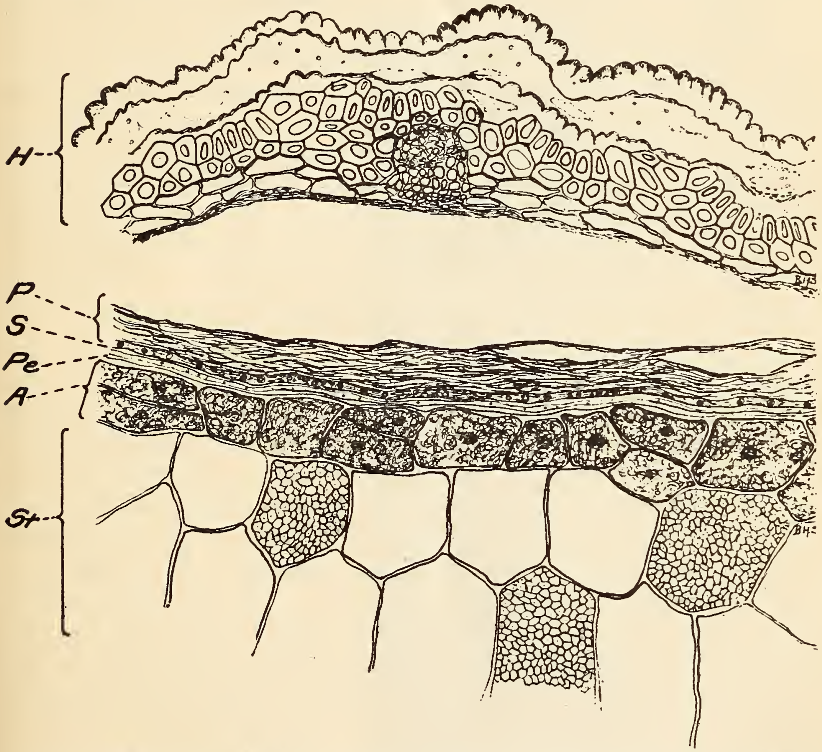

Fig. 2.—Cross section of the hull and outer portion of a rice grain, greatly magnified. *H*, Hull ; *P*, pericarp (including the epicarp, mesocarp, cross cells, and tube cells) ; *S*, spermoderm ; *Pe*, perisperm ; *A*, aleurone layer ; *St*, starch cells.

protein and this constituent is also present in the protoplasm distributed through the endosperm, it is not surprising that only about 10 per cent of the protein of the hulled rice is removed by milling. The oil, however, is largely contained in the germ, and about 85 per cent of the entire oil content of the hulled rice goes into the byproducts. Since the mineral salts of the hulled grain lie mostly in the exterior layers, the proportion of salts is reduced nearly 70 per cent by milling. Interesting, but of less importance, is the reduction of 70 per cent in the crude-fiber content by the removal of the cellulose structure of epicarp and perisperm and a 30 per cent decrease in the quantity of pentosans.

MILLING METHODS.

EVOLUTION OF RICE MILLING.

The rice hull is so stiff and hard as to be quite inedible, and its removal from the grain is in reality the fundamental process of rice milling. To accomplish this, various devices have been used in the United States. The pounding of the grain in a wooden mortar with a pestle by hand was succeeded by the employment of mechanical devices for raising the pestle and by the use of larger mortars and pestles covered with metal on their wearing surfaces. In some localities a further refinement of the process consisted in substituting revolving stones as a hulling agent before the rice was pounded.

In Louisiana the same object was later accomplished by a machine called the "plantation huller," in which the rough rice was hulled and scoured by friction between corrugated iron surfaces. Modern mills employ large revolving stones for removing the hulls and a series of scouring machines for polishing the grain.

PRIMITIVE METHODS.

FARM MORTAR-AND-PESTLE MILLING.

In early times, when the production was small and consumption was confined largely to the producing area, simple and cheap methods of milling were adequate. The farm mortar was made by burning or scraping a conical cavity in a block of hard wood, and the pestle was prepared from a cylindrical stick of similar wood by shaping and pointing each end and cutting down the center to a size suitable for a handle. Such a pestle was about 3 feet long and weighed from 10 to 15 pounds. Figure 3 shows the type of wooden mortar and pestle formerly used in milling rice for home consumption. The rough rice was pounded until practically all the grains had been hulled and the broken hulls, acting as an abrasive, had scoured off a considerable portion of the bran coat. The loose hulls and bran were blown away by the wind when the pounded mass was poured from an elevated pan to a receiver below. Before cooking such rice it was necessary to remove by hand picking the remaining paddy or unhulled grains, which were always present. Since the capacity of a mortar was generally less than a bushel and the operations were all done by hand, this method was inadequate for the milling of rice except on a small scale.

MORTAR-AND-PESTLE MILLS.

As the demand for rice increased, it was found economical to employ larger mortars and mechanical means for pounding and winnowing the grain. The mortars, enlarged to a capacity of 4 to 6 bushels each, were lined with iron, and the pestles, covered with the same metal, weighed 350 to 400 pounds each. All machinery in these mills was operated by power secured from small wood-burning steam engines. The pestles were raised and dropped into the mortars by means of a huge horizontal revolving drum, fitted with spokes which, as the drum revolved, passed into and under slots in the pestles, raising them up, passing out, and dropping them suddenly with a heavy thud into the mass of rice in the mortars. Machine-driven screens and fans were adopted, and the capacity of a mill employing six or eight mortars was over 700 bushels of rough rice per day. Mills of this type, which were located at various points along the South Atlantic coast, were the first to attempt a separation of the clean rice into grades according to size. This was done by the use of flat metal screens.

FIG. 3.—Wooden mortar and pestle used in milling rice by hand.

Very largely increased production in southwestern Louisiana and a demand for a more highly polished product resulted in further mechanical developments in the mills of that region. The rice was first screened to remove foreign matter, such as straw, weed seeds, and mud lumps. It then passed to a pair of hulling stones, a new machine introduced to perform a part of the work formerly done by the mortar and pestle. The rice fell through an opening in the upper stone, and the revolution of this stone, or "runner," over the "bed stone," which was stationary, caused the grains to incline in a semiupright position between the two stones. The "runner," which revolved over the "bed stones" at a distance above it equal to about two-thirds the length of the rice grain, cracked or split the hull, allowed the grain to drop out, and by its revolutions forced grain and hulls along together out of the machine. The runner stone was capable of being raised or lowered to suit the quality and size of the grain in various lots.

From the stones the material passed to a newly introduced combination "screen blower," which fanned out the hulls and partly separated the unhulled, or paddy, grains from the hulled rice. The paddy rice was returned to the stones and the hulled rice conveyed to storage bins above the mortars. In these mills the mortars were used only as scouring machines and removed most of the bran coat, together with the germ, or eye, of the grain. When the rice had been sufficiently pounded, it was transferred to the flour screen and thence to the fine-chaff fan for the separation of the by-products. The rice became heated through friction in the mortars, and it was therefore sometimes placed in cooling bins, where it was stored for eight or nine hours before further milling. The final polishing was accomplished by the friction of the grain in the polisher or brush. This machine consisted essentially of a vertically cylindrical framework which was covered with overlapping pieces of soft moose hide or sheepskin and revolved at a high rate of speed within a cylinder of wire screen. The rice was scoured between the leather and the wire screen and given a highly polished surface. Grading was done on flat metal screens, and the clean products were barreled for the market.

PLANTATION HULLERS.

Several small huller mills are still operating in various parts of Louisiana, cleaning rice for local use. Briefly the process is as follows: Power is secured from a small engine which drives belts for the operation of the mill machinery. The rough rice is first screened free from straw, chaff, and dirt and passed directly into the hopper of the huller. This huller resembles externally a large sausage machine and is composed of a horizontal, tapering, grooved cylinder within which revolves a ribbed shaft. The rice is subjected to a vigorous rubbing of the kernels against each other and to a scraping between the rough iron walls of the tapering cylinder and the ribbed surface of the rapidly revolving core. The grain is next screened and fanned free from hulls and passed a second time through the huller, after which it is again fanned and is ready for consumption. Such milled rice contains a large percentage of broken kernels which are covered with a film of powdery bran.

On account of the small motive power and little machinery used, the daily capacity of such a mill seldom exceeds 40 barrels of rough rice of 162 pounds each. The grower generally has his choice of paying about 50 cents per barrel cash for the milling, in which case he retains the mixed hulls and bran, or of giving 30 cents together with the by-products. The yield of milled rice from a plantation huller approximates 80 pounds per barrel of rough rice of the Honduras type.

MODERN MILLING.

The large profit formerly derived from the modern rice mill, as well as the rapid extension of rice farming in western Louisiana and Texas during the past 20 years, led to an overconstruction of mills. In 1911 competition, which had become so vigorous as nearly to eliminate profits, resulted in the consolidation of about 30 Louisiana mills and the formation of the Louisiana State Rice Milling Company. To secure greater business economy and milling efficiency 12 mills were closed and many of the remaining 18 enlarged. In addition to the 30 mills of the Louisiana State Rice Milling Company, there are in Louisiana 11 independent mills, all operating in 1913, of which 8 are in New Orleans. Twenty mills are located in Texas, and all but two were operating in 1913. In Arkansas six mills were running during 1913 and one was closed. Tennessee has one operating mill at Memphis. On the Atlantic coast there are five mills, all of the mortar-and-pestle type, located in North Carolina, South Carolina, and Georgia, but only one of these is at present operating, and that on a very small scale.

MILLING MACHINERY.

The milling of wheat and of rice are fundamentally opposite. In milling wheat the chief product, flour, must be ground very fine; in milling rice the grains must be kept as nearly whole as possible. According to the present commercial conception, an efficient rice mill is one which properly cleans, scours, and polishes the rice grains with a minimum amount of breakage. This fact must be kept in mind in the study of each machine.

Screens and fans.—The rough rice from the thrashers, stored in bags in the warehouse or in bulk in the elevator bin of the rice mill, generally is thoroughly screened and fanned in a combination screen blower before being conducted into the hopper of the hulling stones. Chaff, weed seeds, mud lumps, and other foreign substances are thus removed, which, if present, would damage the machinery or introduce impurities into the finished products.

Hulling stones.—The first real milling operation consists of removing the hulls from the grain between the hulling stones. These latter are a perfected form of those employed in the old mortar-and-pestle mills already described, and differ little from the stones which are widely used for grinding corn. In a modern rice mill of a daily capacity of 600 barrels of 162 pounds each, two sets of stones are generally employed. Since the revolving motion of the stones tends to keep the grains on end and all the grains in a lot of rice are not uniform in length, it is found most economical to adjust the stones at a sufficient distance apart so that the best and longest grains are not broken and at the same time a maximum percentage of rough rice is hulled. If the stones are set too close together, it is also found that the germs are removed from some of the grains instead of remaining to be scoured off with the bran. The average results of the mechanical analyses of several samples of rice of the Honduras type collected directly from the stones are as follows: Hulled rice, 65.5 per cent; rough rice, 15.3 per cent; and hulls, 19.2 per cent.

Fans.—From the stones the mixture of hulled rice, rough rice, and hulls is elevated to the upper mill floor to be fanned. The fanning device is very similar in this case to the one used in removing the dust and weed seeds from the original rough rice. The same forced air that separates the hulls from the rice usually takes them to the fuel house near the boiler room, where they are eventually used as

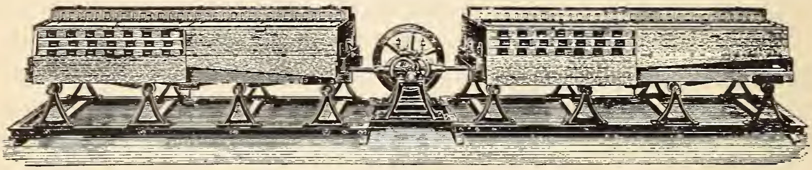

FIG. 4.—Typical paddy machines used in modern rice mills to separate the unhulled rice (paddy grains) from the hulled rice in the process of milling.

fuel for the mill, or, if they are not to be burned, to a grinding machine, where they are prepared for the market. Practically all rice mills make use of the hulls as a source of power for heating the boilers. Analyses of many samples of the Honduras type of rice taken from the fans show how efficiently the loose hulls are removed in this machine. The average results are as follows: Hulled rice, 81.9 per cent; rough rice, 17.2 per cent; and hulls, 0.9 per cent.

Paddy machine.—The paddy machine is a device designed to separate the rough from the clean rice in the mixture, which has been fanned practically free from hulls. Essentially it consists of a large inclined mechanically operated shaker, the surface of which is interrupted at regular intervals with small vertical metallic plates which divide the rice and aid gravity in making the separation. As the shaking proceeds the rough rice grains, being lighter, gradually move upward from the center feed and pass over the high side of the machine into a trough, while the heavier, hulled grains are collected under the lower side. The separation may be varied by changing the speed of shaking, the angle of incline of the platform, or the rapidity of the feed. Four to six paddy machines are generally employed in a mill of 600 barrels daily capacity. The structure and arrangement of two paddy machines are shown in figure 4.

Table I shows the efficiency of the paddy machine in separating the unhulled from the hulled rice. In studying this table, it must be remembered that about 80 per cent of the rice passes out at the lower or clean-rice side of the machine.

TABLE I.—*Average results of analyses of four samples of the Honduras type of rice secured from the feed boxes of paddy machines and of corresponding samples from the troughs at the clean-rice and rough-rice sides.*

Product.	Rice (per cent) from—		
	Feed box.	Clean side.	Rough side.
Clean rice	81.85	98.98	16.56
Rough rice	17.25	1.02	77.68
Hulls	.90	....	5.76

The rice from the rough side of the paddy machines is returned to a pair of small stones which are set close together, where the short kernels are hulled and then combined with the rice from the first stones. The rice from the clean side is now practically free from hulls, but the grains retain the thin brown bran layer as well as the eye, or germ, intact.

Hullers.—The name "huller," given to the next machine in the milling process, is very misleading, because in reality this machine is used for removing the bran layer from the grain which has been hulled by the stones and freed from rough rice by the paddy machine. The word "huller" is universally understood in this connection in the rice industry, and hereafter when the word appears in this bulletin it will designate the machine which receives the rice from the paddy machine and scours off the outer bran layers. The name was probably inherited from the similar machine, the plantation huller already described, which removed hulls as well as bran. The modern huller is somewhat smaller but otherwise very similar to that already described, and six or seven machines are necessary in a 600-barrel mill. The grain from the clean-rice side of the paddy machine is conducted to the feed hopper of the huller and thence passes into the cavity of the machine. A part of the bran layer on the outside of the grain and most of the germ are removed, largely by scouring between the rough inside iron walls of the tapering cylinder and the grooved surface of the rapidly revolving core. Figure 5 shows the type of huller used in modern rice mills. In this machine the milling quality of the rice is put to a severe test and the grain much whitened by the elimination of the brown exterior bran coats. In some mills the rice is passed through a second set of hullers.

Bran reel.—The bran reel receives the product from the hullers and separates the rice from the powdery bran. This reel is composed of a large octagonal framework covered with fine wire screen, the square meshes of which are 14 per linear inch. The reel is set on a slight incline and its slow revolving motion takes the rice, which enters at the higher end, through its length of 9 feet in about 5 minutes. As the reel revolves, the rice constantly falls from side to side and forces the bran through the wire covering.

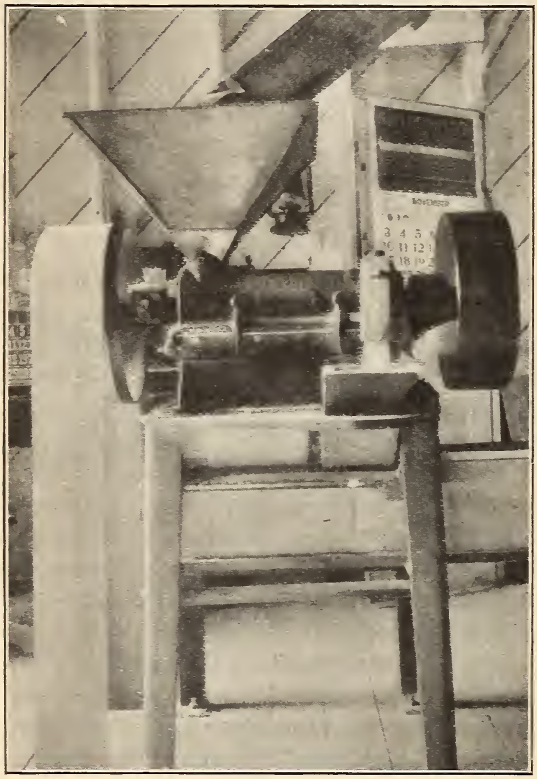

Fig. 5.—A typical rice huller, showing its exterior construction, belting, hopper, feed, milled rice, etc.

Pearling cone.—The pearling cone, which has recently been introduced in many mills to supplement the work of the hullers, is essentially the same machine that is used in the pearling of barley. The principal working part of the machine is a frustrum of a cone covered with a composition stone; this is surrounded by a sieve mantle composed of close-meshed heavy iron wire. The rice is fed from above between the stone and the sieve and is thoroughly rubbed before passing out at the bottom. The severity of the scouring is regulated by raising or lowering the stone, thus decreasing or increasing its distance from the wire screen. The best milling practice now approves the use of the pearling cone, because with its use the grain may be more gradually scoured than where the hullers alone are used and the breakage can also be kept lower. The loosely adhering bran resulting from the action of the pearling cone is removed from the rice in a bran reel. This bran is generally combined with that removed by the hullers, but is occasionally mixed with the polish from the brush or even bagged and sold locally as rice meal.

Brush and brewer's reel.—The brush is the last scouring machine in the milling process. On account of the rapid feed necessary in securing the best results from the brush, the rice from the bran reel following the pearling cone is stored in large bins situated above the brush. This latter machine has already been described as the polisher of the mortar-and-pestle mill. In the modern mill it has been found advantageous to substitute pigskin for moose hide or sheepskin and to increase the speed of the machine. The very thin layer of bran which is rubbed off is forced through the surrounding screen as a light-brown powder, called rice polish. The rice kernel at this point is reduced approximately 10 per cent of its weight after the removal of the hull. As a rule, when a coating of glucose and talc is to be applied later in the process, the rice is not subjected to such a severe scouring in the brush as when it is to be sold as uncoated rice. From the brush the rice, containing all sizes from the most nearly perfect whole grains to the smallest particles, is passed into the brewer's reel for the first step in grading. This reel differs from that which removes the bran only in that the wire screen covering has 10 meshes instead of 14 to the inch in each direction. The brewer's rice which passes through the screen of this reel is never coated with glucose and talc, since its value is small and not increased by such a process involving extra expense.

Trumbles.—When the rice is to be coated with glucose and talc, as is generally done, it is transferred directly from the brewer's reel to the trumble for this purpose. The trumble is a cylinder about 9 feet long and 4 feet in diameter set on an incline of about 15° from the horizontal and revolved by a gearing on the outside. It is often provided with a steam pipe through its axis for raising the temperature of the rice, to effect a higher luster in cold weather. The rice, together with the coating materials, is introduced at the higher end of the trumble, and the shiny appearance is produced on the grain as it moves slowly round and round and ultimately pours out at the lower end. To the inside surfaces of the trumble are fixed several small strips of wood, which carry the rice up the side and let it fall again as the cylinder revolves, thereby increasing the friction on the rice grains. Glucose of a good quality, which is generally heated and mixed with a small proportion of water, is fed from a tank in a constant small stream upon the rice as it enters the trumble. Talc is introduced at the same place by means of a screw feed connected with a supply box. The quantity of each coating material added is regulated by the miller to suit the quality of the particular lot of rice being milled. No other coating materials than those mentioned have been observed in use in the mills of the United States. In some cases a second trumble without glucose and talc feeds supplements the work of the first, and it is generally conceded that the extra friction gives to the rice a brighter and more desirable luster.

Table II shows the percentage of rice-coating material used in a large number of mills in Louisiana, Texas, and Arkansas. The figures given were calculated by ascertaining the daily output of the mills and the corresponding gallons or pounds of coating materials actually being applied. The considerable variation in the quantities of the coating material used, as shown in the maximum and minimum columns of the table, is due to the difference in the quality of the various lots of rice and to the interpretation of trade demand by the mill management. The averages show that the Honduras and Japan types of rices receive about the same quantities of coating materials, which approximate two parts of glucose and one part of talc per thousand parts of rice.

TABLE II.—*Glucose and talc added to milled rice.*

Type of rice.	Number of samples.	Glucose (per cent).			Talc (per cent).		
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Honduras	29	0.20	0.46	0.06	0.07	0.30	0.02
Japan	8	.19	.26	.09	.09	.20	.05

Grading machines.—From this stage to the ultimate bagging the problems met with pertain to the grading of the clean rice. However, if the rice is damaged or very inferior because of the presence of red rice, it is often bagged ungraded and sold as "line" rice. The shaker frame, which was the earliest device used for grading rice, is simply a framework, mechanically operated, which supports a set of inclined flat metal screens. These screens are removable at will and are numbered according to the sizes of the round perforations in them. The unit of measure is a sixty-fourth of an inch; hence, a No. 8 screen has holes eight sixty-fourths of an inch in diameter. Shaker frames are still used in practically all mills, to aid in the grading work. In most cases a considerable proportion of the "fancy head" grade is removed on the screens before the rice goes to the cockle cylinder.

If the quality of the rice being milled is exceptionally good an extra fancy head grade is made, which consists of the largest and most nearly perfect grains of the lot, with only a small percentage of broken particles. This commercial grade, if of the Honduras type, consists of that rice which does not pass through a No. 8½ screen on the shaker frame, and, if Japan, a No. 7½ screen. In passing the rice over the screens of the shaker frame the small quantity of finely broken rice which failed of separation in the brewer's reel or resulted from a slight breakage within the trumbles is removed through a No. 5½ screen and combined with the other brewer's rice.

Long, revolving, cylindrical grading reels replaced in some cases the earlier shaker frames. Such a reel consisted of a framework divided equally into four sections, each of which was covered with a wire screen. The screens, which could be replaced, were of various-sized mesh, and by making substitutions the character of the separation could be fairly well controlled. Beneath each section was a trough to receive the rice which passed through the screen of that section. The grading reels are now used only to assist the more efficient cockle cylinders described in the following paragraph.

The cockle cylinder is by far the most valuable and widely used device for grading rice. It is a form of the machine extensively employed in removing cockle from wheat previous to its milling, and has been in use for grading rice for about 10 or 12 years. It consists of a metal cylinder, the inside surface of which contains indentations stamped or bored in the metal. The cylinder is set on an incline and propelled from the outside, and in action revolves around a supporting stationary axle, to which is also fastened an adjustable curved metal apron. The apron extends nearly across the diameter of the cylinder and throughout its entire length. The rice to be graded is introduced on the floor of the cylinder at its upper end. As the cylinder revolves, the smallest particles of rice fall into the depressions, are carried upward through a part of a revolution, and when above the suspended apron, they fall upon it. Since the apron receives all rice particles which are carried by the surrounding cylinder above its edge, the size separation of the rice may be changed at will by adjusting the position of the apron on the axle and thus raising or lowering the edge of the apron. Each cylinder is designated according to the diameter of its depressions, which, as in the case of the flat metal screens, are expressed in terms of sixty-fourths of an inch. In most mills three cockle cylinders, Nos. 10, 12, and 14, are set up in the same framework and are operated together, and frequently two such sets are placed side by side in a double frame. It is the customary practice in milling the Honduras type of rice to conduct the ungraded rice from the shaker frame to the floor of cockle cylinder No. 10, which takes out the smallest particles and sends the remainder to cylinder No. 12 below. Broken grains of the next larger size are separated on the apron of cylinder No. 12 and the remainder goes down to cylinder No. 14, which performs its work in a similar way. The rice from the apron in cylinder No. 10 is ordinarily bagged as the screenings grade of clean rice, the particles from the aprons of Nos. 12 and 14 are mixed and sold as the second head grade, and the remainder from the floor of No. 14 constitutes the fancy head grade. Each separated grade is conducted through a wooden chute to the first floor of the mill, where it is packed for the market.

The above-described separations apply only to the Honduras type of rice. The Japan type is sorted in a similar way, except that all broken particles separated by the cockle cylinders are ordinarily mixed and sold as Japan type screenings, thus making three grades instead of four.

Weighing and bagging machines.—All clean rice, except the brewer's rice and a small amount which is packed in cartons, is shipped from the mill in closely woven burlap bags, or pockets, of 100 pounds each. In many mills automatic machines for weighing the rice and sewing the filled bags have been installed with satisfactory results.

EFFECTS OF MILLING ON RICE.

It is the purpose of modern rice milling to free the grain from hulls and then to scour and grade it so as to produce a maximum amount of the highly polished rice which, on account of its bright luster, seems to appeal to the trade. The scouring process, to be effective in removing the bran layers, is so severe that a large proportion of the rice grains are broken, the weight of the individual grains is materially decreased, and important chemical constituents are removed.

MECHANICAL EFFECT.

METHOD OF ANALYSIS.

A 25-gram portion of the thoroughly mixed sample was weighed out for the mechanical analysis. This was shaken on a nest of two flat metal screens with round holes six sixty-fourths and five sixty-fourths of an inch in diameter, respectively. The particles which passed through the larger holes, but remained on the screen with the smaller holes, were weighed and considered as one-third grain, while those which also passed through the smaller holes were classified as less than one-third grain. The remainder of the sample was then separated into three further sizes by hand picking with small forceps. The whole grains were first removed and the remainder divided into particles of more and particles of less than one-half grains of the average size occurring in the sample under examination. The weight of each of the five separations was then taken and the results calculated to a percentage. The divisions, according to the size of particles, are therefore (1) whole grains, (2) three-fourth grains, (3) one-half grains, (4) one-third grains, (5) less than one-third grains. While these designations do not describe with absolute accuracy the classes of separated rice, they will serve for comparison and are more convenient for use in the tables which follow than exact descriptions could be. Furthermore, the ideas to be presented are more readily grasped than if the separations were designated merely by consecutive letters or numbers. The weight of 1,000 kernels was determined by counting and weighing 250 of the whole grains, separated as previously described.

BREAKAGE IN MILLING.

Unfortunately no figures are available from the literature which show the breakage of rice in the mortar-and-pestle mills. It is asserted, however, that this breakage was surprisingly small, considering the great weight of the iron-clad pestle. The decline in the use of these mills was undoubtedly due to other economic factors, such as their comparatively small daily output, considering the equipment involved, and their incapacity for fine adjustment to suit varying qualities of rice.

The "plantation hullers," on the other hand, cause great breakage, especially to rice of the Honduras type. The writers have examined samples taken from one lot of the Honduras type and three lots of the Japan type milled in "plantation hullers." Of the Honduras lot samples were secured of the partly milled grain and of the finished product, while the samples of the Japan type all represent the finished milled rice.

In Table III special attention is called to the excessive breakage of the rice. The action of the second hulling as well as the first is shown to be very disastrous to the whole-grain content.

Table III.—*Size separation of rice of the Honduras type milled in "plantation hullers."*

Milling stage.	Grains (per cent).				
	Whole.	Three-fourths.	One-half.	One-third.	Less than one-third.
After first hulling	32.0	12.7	44.1	7.0	4.2
Finished product	9.6	8.8	38.8	24.8	18.0

Fifty-six series of samples of the Honduras type of rice were secured from big modern mills in all parts of the rice-growing belts of Louisiana, Texas, and Arkansas, representing various grades and qualities of rough rice. Table IV, which follows, has been prepared from the figures showing the mechanical analyses of these series. The analytical results for the rough rice have been omitted from the table, as the figures are not easily comparable and have no particular bearing on the phase in question.

TABLE IV.—*Size separation of samples of rice of the Honduras and Japan types from various milling machines in modern mills.*

Milling stage.	Average of 56 series of the Honduras type of grains (per cent).					Average of 25 series of the Japan type of grains (per cent).				
	Whole.	Three-fourths.	One-half.	One-third.	Less than one-third.	Whole.	Three-fourths.	One-half.	One-third.	Less than one-third.
Paddy machine	74.35	8.76	15.33	1.16	0.40	92.38	2.38	4.38	0.65	0.21
Hullers and pearling cone	52.51	13.38	24.73	5.67	3.71	84.22	4.30	7.66	2.44	1.38
Brush, brewer's rice:										
In	49.96	13.56	25.51	6.54	4.43	80.37	4.89	8.54	3.83	2.37
Out	52.57	14.62	26.28	5.11	1.42	82.52	4.84	8.96	2.88	.80
Trumbles	51.69	14.44	27.18	5.49	1.20	82.57	4.70	8.29	3.61	.83

The five points in the milling process at which these samples were taken are considered very significant. The first is rice from the paddy machine, and this shows the condition of the grain after the removal of its hull in the stones and the separation in the paddy machine of the remaining portion of rough rice. This, then, is brown rice, retaining the bran coat and germ nearly intact. Naturally, the whole-grain content is comparatively large, but it has been found that badly sun-cracked rice often shows a considerable amount of breakage even at this point.

The second line is rice from the hullers and pearling cone. Inasmuch as the pearling cone performs the same work in some mills as is done by the hullers in others, the results are combined in the table, so that the figures show the condition after the final scouring operation in each case, before the material goes to the brush. The severe scouring which the grain undergoes in these machines is clearly shown by the marked decrease in the percentage of whole grains from that of the previous line. It is at this stage that most of the breakage in rice milling occurs.

The third line shows the rice after it has been scoured by the brush and still contains all the small particles of brewer's rice. The fourth line gives the percentage composition after most of the brewer's rice has been removed in the brewer's reel. It is seen that the brush reduces the whole grain content only about 2½ per cent. On the other hand, a small increase in the percentage of whole grains naturally results from the removal by the brewer's reel of the fine particles of brewer's rice.

The last line shows the ungraded rice as it leaves the trumbles, where it has been rolled and heated after having received in many cases an application of coating materials. A slight breakage has also occurred here. The rice grain normally is hard and brittle and greatly subject to fracture by a rapid change in temperature. Care is used by the miller to shield, as far as possible, from currents of cool air or from cold metal the rice which has become heated in the brush or trumble.

Twenty-five similar series of the Japan type of rice were secured and analyzed in the same way, and the results are also shown in Table IV. Breakage in milling rice of this type is seen to follow the same lines as shown for the Honduras type, but less injury occurs, on account of the short, compact shape of the grain.

Figure 6 illustrates the most important data given in Table IV.

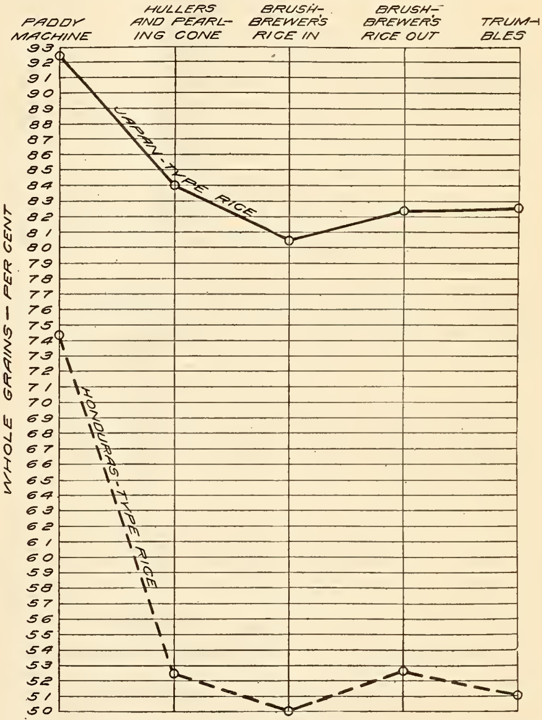

FIG. 6.—Diagram showing the decrease in the percentage of whole grains in the Honduras and Japan types of rice during the course of the milling process.

EFFECT OF WEIGHT PER THOUSAND KERNELS.

Nine series of samples of rice of the Honduras type and five series of the Japan type from modern mills were analyzed to show the effect of the milling machines on the weight of the kernels. The whole grains were picked from a portion of each sample and the weight of 250 whole grains ascertained in every case. From this the weight per 1,000 kernels was calculated. Attention is called to the marked decrease in weight of the kernels caused by the action of the hullers and pearling cone. Some decrease in weight is caused by the brush, and the slight increase after passage through the brewer's reel is probably due to the removal at that point of a few of the smallest whole grains. The addition of the glucose and talc coating slightly increases the weight of the grains in the trumbles. A comparison of the relative sizes or weights of the grains of the two types is clearly shown in Table V.

TABLE V.—*Effect of various rice-milling machines on the weight per 1,000 kernels of rice.*

Milling stage.	Average weight of rice samples (grams). Honduras type, 9 samples.	Japan type, 5 samples.
Paddy machine	24.13	22.44
Hullers and pearling cone	22.80	21.50
Brush, brewer's rice:		
In	22.07	20.20
Out	22.20	20.40
Trumbles	22.35	20.56

Figure 7 illustrates the data contained in Table V and shows the gradual decrease in weight per 1,000 kernels of rice of the Honduras and Japan types as the milling process proceeds.

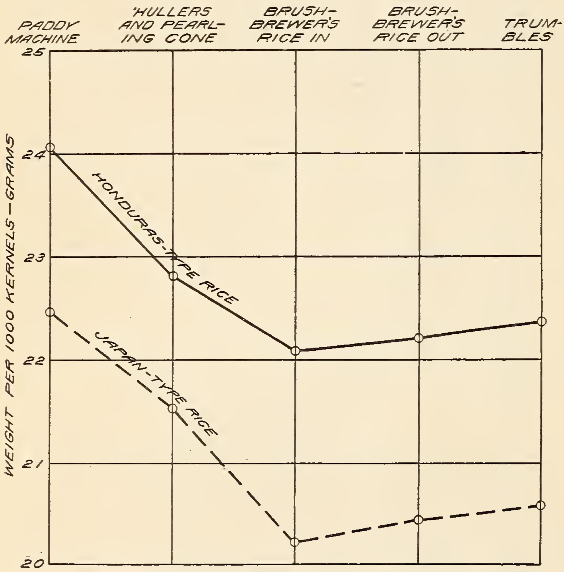

FIG. 7.—Diagram showing the effect of various milling machines on the weight per thousand kernels of the Honduras and Japan types of rice.

CHEMICAL EFFECT.

Figures in Louisiana Agricultural Experiment Station Bulletin 24 (first series), 1889, show the difference in chemical composition of one lot of rice at various stages in the old mortar-and-pestle milling process in Louisiana.

Similar results were obtained by McDonnell (1901), South Carolina Agricultural Experiment Station Bulletin 59, on the product of a South Carolina mill of the same type. Apparently the scouring proceeded further, however, than in the case of the Louisiana mill. The analyses of both lots are shown in Table VI.

The chemical analyses of samples of rice of the Japan type milled in a "plantation huller," also given in Table VI, were made in the Bureau of Chemistry, Department of Agriculture, according to the methods of the Association of Official Agricultural Chemists. For better comparison, these results are also calculated to the moisture-free basis. They show that the product from the "plantation huller" is lower in percentage of ash, ether extract, and crude fiber than the rice from the old mortar-and-pestle mills, indicating a more thorough scouring of the grains in the huller.

TABLE VI.—*Chemical composition of samples of rice in various stages of milling and of different qualities.*

Sample analyzed.	Constituents (per cent).								
	Moisture.	Ash.	Ether extract.	Crude fiber.	Protein.	Calculated to moisture-free basis.			
						Ash.	Ether extract.	Crude fiber.	Protein.
MORTAR-AND-PESTLE MILL.									
Louisiana lot (Honduras type), 1889:									
Rough rice	10.95	5.45	2.58	9.28	7.44	6.12	2.89	10.42	8.35
Other stages—									
From hulling stones	12.12	2.55	2.10	3.03	8.09	2.90	2.39	3.45	9.21
Pounded	12.42	2.38	2.50	2.55	8.14	2.72	2.85	2.91	9.29
From cooling floor	12.75	.82	1.05	.72	7.74	.94	1.20	.83	8.87
Clean	12.85	.73	.38	.47	7.52	.83	.44	.54	8.63
South Carolina lot, 1901:									
Rough rice (dried at 50° C.)	5.21	6.74	2.36	8.07	7.19	7.11	2.49	8.51	7.59
Polished rice—									
Whole	12.79	.42	.24	.33	7.38	.48	.27	.38	8.46
"Middling"	13.69	.40	.43	.33	6.88	.46	.49	.38	7.97
Small	13.92	.51	.73	.39	6.75	.59	.84	.45	7.84
"PLANTATION HULLER."									
Rice of the Japan type:									
Good quality	10.28	.30	.19	.20	7.75	.33	.21	.22	8.64
Fair quality	9.96	.32	.23	.25	6.38	.36	.26	.28	7.09
Poor quality	10.09	.31	.19	.21	7.00	.34	.21	.23	7.79

Chemical analyses were made of four series of mill samples of Honduras rice and of three series of samples of Japan rice. These samples, which represent different grades of rough stock, were obtained in various parts of Louisiana, Texas, and Arkansas and are considered to typify the chemical effect of rice milling as now exemplified in those States. Table VII gives the results of these chemical analyses.

TABLE VII.—*Chemical composition of the Honduras and Japan types of rice from various milling machines of modern rice mills.*

Type.	Grade.	Constituents (per cent).										
								Calculated to moisture-free basis.				
		Moisture.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.
RICE OF THE HONDURAS TYPE.												
Series 1:												
Rough rice	1	11.35	5.26	1.57	9.05	7.38	6.18	5.93	1.77	10.21	8.32	6.97
From paddy machine		12.33	1.13	1.28	1.10	8.06	2.56	1.29	1.46	1.25	9.19	2.92
From hullers		12.64	.39	.08	.32	7.63	2.04	.45	.09	.37	8.73	2.33
From pearling cone		11.91	.35	.08	.32	7.63	1.72	.40	.09	.36	8.66	1.95
From brush, brewer's rice, out		10.80	.34	.24	.31	7.63	1.98	.38	.27	.35	8.55	2.22
From trumbles, uncoated		11.82	.36	.21	.20	7.44	1.71	.41	.24	.23	8.44	1.94
Series 2:												
Rough rice	1	10.81	5.75	1.48	9.16	7.66	6.21	6.45	1.66	10.27	8.59	6.96
From paddy machine		12.40	1.31	2.00	.95	9.22	2.61	1.50	2.28	1.08	10.52	2.98
From brush, brewer's rice, out		12.26	.35	.15	.35	8.41	1.91	.40	.17	.40	9.59	2.18
Series 3:												
Rough rice	1	12.42	4.63	1.31	7.00	7.56	5.12	5.28	1.50	7.99	8.63	5.85
From paddy machine		13.18	1.21	1.70	.78	8.75	2.10	1.39	1.96	.90	10.08	2.40
From hullers		13.08	.80	.58	.46	8.12	1.68	.92	.67	.53	9.34	1.93
From pearling cone		13.09	.58	.47	.28	8.12	1.34	.67	.54	.32	9.34	1.54
From brush, brewer's rice, out		13.23	.43	.26	.19	8.43	1.40	.50	.30	.22	9.72	1.61
From trumbles, uncoated		13.09	.48	.28	.25	7.93	1.35	.55	.32	.29	9.12	1.55
Series 4:												
Rough rice	5	10.49	5.97	1.96	9.58	7.31	6.10	6.67	2.19	10.70	8.17	6.81
From paddy machine		11.38	1.06	2.20	1.14	8.25	2.39	1.20	2.48	1.29	9.31	2.70
From hullers		11.96	.40	.55	.38	7.63	1.99	.45	.62	.43	8.67	2.26
From brush, brewer's rice, out		11.26	.33	.34	.35	7.75	1.90	.37	.38	.39	8.73	2.14
From trumbles, coated		11.16	.35	.33	.33	7.88	1.92	.39	.37	.37	8.87	2.16
Average of the four series:												
Rough rice		11.27	5.40	1.58	8.67	7.48	5.90	6.08	1.78	9.79	8.43	6.65
From paddy machine		12.32	1.18	1.79	.99	8.57	2.42	1.35	2.05	1.13	9.78	2.75
From hullers		12.56	.53	.40	.39	7.79	1.90	.61	.46	.44	8.91	2.17
From pearling cone		12.50	.47	.28	.30	7.88	1.53	.54	.32	.34	9.00	1.75
From brush		11.89	.36	.25	.30	8.06	1.80	.41	.28	.34	9.15	2.04
From trumbles		12.02	.40	.21	.26	7.75	1.66	.45	.31	.30	8.81	1.88
Loss, paddy machine to trumbles								66.00	85.00	73.00	10.00	32.00
RICE OF THE JAPAN TYPE.												
Series 1:												
Rough rice	1	10.72	5.36	1.78	7.68	6.31	5.51	6.00	1.99	8.60	7.07	6.17
From paddy machine		11.96	1.13	1.92	.86	7.09	2.63	1.28	2.18	.98	8.05	2.99
From hullers		12.20	.81	1.32	.56	7.00	2.03	.92	1.50	.64	7.97	2.31
From pearling cone		12.71	.51	.57	.39	6.59	1.86	.58	.65	.45	7.55	2.13
From brush, brewer's rice, out		12.17	.29	.09	.33	6.66	1.99	.33	.10	.38	7.58	2.27
From trumbles, coated		12.27	.31	.26	.36	6.16	1.66	.35	.30	.41	7.02	1.89

Table VII.—*Chemical composition of the Honduras and Japan types of rice from various milling machines of modern rice mills*—Continued.

Type.	Grade.	Constituents (per cent).										
								Calculated to moisture-free basis.				
		Moisture.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.
RICE OF THE JAPAN TYPE—continued.												
Series 2:												
Rough rice	3	11.15	4.57	1.80	7.81	7.00	5.73	5.14	2.03	8.79	7.88	6.45
From paddy machine		12.83	1.12	1.69	.96	7.81	2.60	1.28	1.82	1.10	8.96	2.98
From hullers		13.02	.56	.47	.40	7.16	1.91	.64	.54	.46	8.23	2.20
From pearling cone		12.87	.36	.18	.31	7.06	1.94	.41	.21	.36	8.10	2.22
From brush, brewer's rice, out		12.41	.31	.40	.38	7.06	1.73	.35	.46	.43	8.06	1.97
From trumbles, coated		11.55	.32	.06	.34	7.19	2.12	.36	.07	.38	8.02	2.40
Series 3:												
Rough rice	5	11.27	5.48	1.65	8.30	6.88	5.21	6.18	1.86	9.35	6.96	5.87
From paddy machine		12.35	1.14	.95	.72	6.81	1.61	1.30	1.08	.82	7.77	1.84
From hullers		15.87	.72	.20	.31	6.31	1.34	.86	.24	.39	7.50	1.59
From pearling cone		14.55	.33	.18	.16	6.12	.99	.39	.21	.19	7.16	1.16
From brush, brewer's rice, out		13.88	.35	.16	.16	6.12	1.11	.41	.19	.19	7.11	1.29
From trumbles, uncoated		13.68	.39	.24	.17	6.06	1.26	.45	.28	.20	7.02	1.46
Average of the three series:												
Rough rice		11.05	5.14	1.74	7.93	6.50	5.48	5.77	1.96	8.91	7.30	6.16
From paddy machine		12.38	1.13	1.52	.85	7.24	2.28	1.29	1.69	.97	8.26	2.60
From hullers		13.70	.70	.66	.42	6.82	1.76	.81	.76	.50	7.90	2.03
From pearling cone		13.38	.40	.31	.29	6.59	1.60	.46	.36	.33	7.60	1.84
From brush		12.82	.32	.22	.29	6.61	1.68	.36	.25	.33	7.58	1.84
From trumbles		12.50	.34	.19	.29	6.47	1.68	.39	.22	.33	7.35	1.92
Loss, paddy machine to trumbles								70.00	87.00	66.00	12.00	26.00

A careful study of the averages of the Honduras type of rice, calculated to a moisture-free basis, is significant and interesting. The ash content is reduced very markedly when the hulls are removed, and one-half of the ash which remains is removed by the scouring work of the hullers. During the remainder of the process the decrease is gradual. The total loss by the scouring process, that is, from paddy machine to trumbles, is 66 per cent, or two-thirds of the ash of the hulled rice.

The percentage of ether extract or fat is generally increased by the removal of the hulls, since the fat or oil is located principally in the eye, or germ, of the grain. However, if the stones are not properly adjusted, it sometimes happens that a portion of the germ is broken off at this time, thereby causing the fat content of the hulled rice to be lower than that of the rough rice. The fat content of the hulled rice is reduced more than three-fourths in the hullers, but through the remainder of the process the reduction is gradual and small. The total loss of fat in scouring is 85 per cent.

The crude-fiber content of the rice is reduced 88 per cent when the hulls are removed, and 73 per cent of the remainder is lost during the process of scouring.

The protein figure rises on the removal of the hulls, as was the case with the fat content. It is especially worthy of notice that only 10 per cent of the protein present in the hulled grain is lost in scouring. This has already been explained by the fact that the protein-bearing aleurone layer is not removed during scouring and that the protoplasm which contains protein is disseminated throughout the starchy portion of the endosperm.

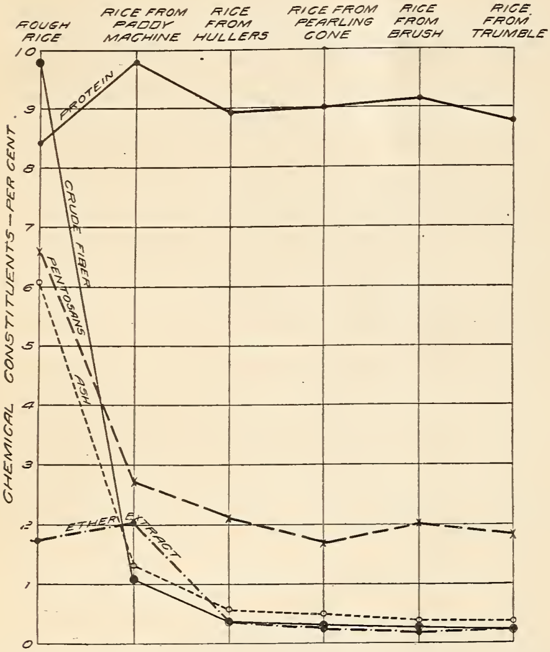

Fig. 8.—Diagram showing the effect of modern rice milling machines on the ash, ether-extract, crude-fiber, protein, and pentosan content of rice of the Honduras type.

Approximately 60 per cent of the pentosan content is removed with the hulls, and 32 per cent of the remainder is lost during the process of scouring.

The loss of the various chemical ingredients of rice of the Japan type corresponds closely to that given for that of the Honduras type.

Figures 8 and 9 illustrate the data contained in the averages of Table VII, calculated to a moisture-free basis.

MILLED RICE AND ITS BY-PRODUCTS.

MECHANICAL ANALYSES AND MILL YIELDS.

The grading devices employed in the modern rice mill permit the milled rice to be separated according to the size of the particles into almost any character of grades desired. Mill and trade practice, however, has outlined roughly six grades of the Honduras type and three grades of the Japan type, based entirely, or nearly so, on the size of the particles or the percentage of whole grains. Several other factors affect the commercial value of various lots within the same grade. These factors in relative importance are (1) color, (2) proportion of grains damaged by heat or by insects, (3) presence of weed seeds, and (4) presence of unhulled, or paddy, rice grains. For the purpose of this paper, only the size separations will be considered.

RICE OF THE HONDURAS TYPE.

The commercial grades of the Honduras type of rice generally now made in the mills are (1) extra fancy head or triple-screened rice (made only when the rough rice is of exceptionally good quality); (2) fancy head, or "head" rice; (3) second head rice; (4) screenings; (5) brewer's rice; and (6) line (ungraded) rice These designations are commonly used in rice mills, and less commonly by produce exchanges in their quotations. They are strictly trade terms in origin and in use and are not the result of any ruling by the Department of Agriculture.

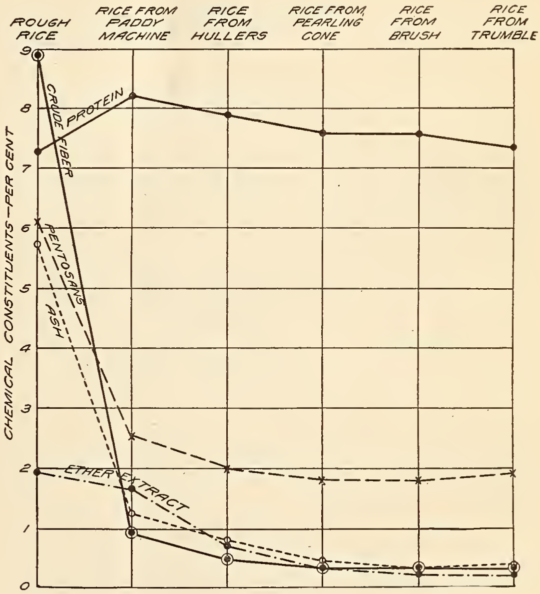

FIG. 9.—Diagram showing the effect of modern rice milling machines on the ash, ether-extract, crude-fiber, protein, and pentosan content of rice of the Japan type.

The graded samples of rice which are about to be described were secured during 1912 and 1913 from all parts of the rice-growing sections of Louisiana, Texas, and Arkansas. They were obtained principally from mills, but a few came from rice brokers and other sources. Mechanical analyses were made of the samples secured, in the same way as previously described for the samples from the milling machines.

The grade known as extra fancy head, also known as triple screened, is rarely made and is not one of the common commercial grades. The mill yield approximates 30 pounds per barrel of 162 pounds of rough rice. The results of analyses of the samples of this grade are given in Table VIII.

Seventy-five samples of the fancy head, or "head," rice, as it is also termed, were secured. The mill yield of this grade varies from 45 to 85 pounds per barrel of rough rice, with an average of about 59 pounds when no extra fancy head grade is made. The results of the analyses are given in Table VIII.

Table VIII also shows that the second head grade is composed principally of half grains, but contains also a large percentage of three-fourths grains. The mill yield varies from 10 to 30 pounds per barrel of rough rice, with an average of 19 pounds.

TABLE VIII.—*Size separation of rice of the Honduras type.*

Separations.	Extra fancy head, or triple-screened, grade (9 samples).			Fancy head, or "head," grade (75 samples).			Second head grade (48 samples).		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Whole grains......per cent..	89.96	96.80	82.00	81.28	94.40	42.80	1.82	7.60	0
Three-fourths grains...do....	8.49	14.40	2.40	13.11	36.80	4.40	21.47	58.80	3.20
One-half grains.........do....	1.51	4.80	0	5.40	34.40	0	70.69	93.60	36.00
One-third grains........do....	.04	.40	0	.20	4.00	0	5.64	23.60	.40
Less than one-third grains, per cent..................	0	0	0	.01	.40	0	.38	1.60	0

Separations.	Screenings grade (48 samples).			Brewer's grade (53 samples).			Line grade (9 samples).		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Whole grains......per cent..	0.71	7.60	0	0.26	1.60	0	53.91	64.80	30.80
Three-fourths grains...do....	4.23	24.00	0	.22	2.20	0	14.31	22.40	8.40
One-half grains.........do....	56.08	81.20	10.00	2.89	26.40	0	27.25	46.40	18.80
One-third grains........do....	32.59	63.60	7.60	26.28	81.80	2.40	4.00	12.40	.80
Less than one-third grains, per cent..................	6.39	44.40	0	70.35	97.60	14.80	.53	2.00	0

The screenings grade contains principally half grains, but differs from second head rice in that it contains but few three-fourths grains and a large proportion of one-third grains. The mill yield varies from 5 to 25 pounds per barrel of rough rice, with an average of 15 pounds. The figures for this grade are given in Table VIII.

The brewer's rice grade contains the smallest particles of milled rice and is composed almost entirely of pieces less than one-third of a grain in size. The mill yield varies from 3 to 13 pounds per barrel of rough rice, with an average of 8 pounds. The results of the analyses are given in Table VIII.

The mill yield of line rice approximates 89 pounds per barrel of rough rice, and the grade includes all the clean product except brewer's rice. As would be expected, there is a very wide variation in the proportions of the particles of different sizes in this grade. Table VIII gives the results of the analyses.

RICE OF THE JAPAN TYPE.

The commercial grades of the Japan type of rice generally now made in the mills are (1) fancy head, or "head," rice; (2) screenings; (3) brewer's rice. Samples of this type of rice were obtained from the same sources and the analyses performed in the same way as previously described for rice of the Honduras type. Fancy head rice is composed very largely of whole grains. The whole-grain percentage is larger than in the corresponding grade of the Honduras type, because the shape of the kernels of the Japan type is more nearly round; consequently, there is a smaller amount of breakage. The mill yield of this commercial grade varies from 92 to 105 pounds per barrel of rough rice and averages 96 pounds. Table IX gives the analytical results for this grade.

TABLE IX.—*Size separation of rice of the Japan type.*

Separations.	Fancy head, or "head," grade (75 samples).			Screenings grade (18 samples).			Brewer's grade (18 samples).		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Whole grains......per cent..	90.43	98.40	76.40	4.58	18.80	0	0.93	11.00	0
Three-fourths grains...do....	3.95	15.60	1.20	11.89	26.40	0	.36	2.80	0
One-half grains........do....	5.08	16.80	0	50.11	70.00	26.40	3.53	16.00	0
One-third grains.......do....	.50	2.80	0	30.30	54.80	3.20	29.11	76.40	1.80
Less than one-third grains, per cent..................	.04	.40	0	3.12	12.40	0	66.07	98.20	16.80

The only commercial grade of broken Japan-type rice used as such for food is that of screenings. The results of mechanical analyses given in Table IX show that it is very similar to Honduras screenings, but the yield is much smaller. In commercial practice the two are often mixed. The mill yield varies from 3 to 11 pounds per barrel of rough rice and averages 5 pounds.

Japan-type brewer's rice is not distinguished commercially from Honduras brewer's rice, and the two are used interchangeably to supply the trade. The mill yield varies from 3 to 10 pounds per barrel of rough rice, with an average of 5 pounds. The analytical results from the samples of this grade are given in Table IX.

BY-PRODUCTS.

The mill yield of rice bran varies with the severity of scouring and the texture of the rice, and approximates 22 pounds per barrel of 162 pounds of rough rice of the Honduras type and 20 pounds for the Japan type. Rice polish approximates in yield 6 pounds per barrel of rough rice for both the Honduras and the Japan types, but, like the bran, it varies considerably with mill practice and the character of the grain. Rice hulls and the intangible mill loss together amount to about 33 pounds for rice of the Honduras type and 30 pounds for the Japan type. The hulls on the Honduras type of kernel are somewhat heavier in proportion than those on the Japan type of grain.

TABLE X.—*Yield of cleaned rice by grades and of by-products obtained from the milling of 1 barrel of rough rice of 162 pounds.*

Cleaned rice and by-products.	Average yield (pounds).	
	Honduras type.	Japan type.
Fancy head, or "head"	59	96
Second head	19	.....
Screenings	15	5
Brewer's rice	8	5
Total cleaned rice	101	106
Bran	22	20
Polish	6	6
Hulls and milling loss	33	30
Total by-products and milling loss	61	56

Figure 10 illustrates the data given in Table X and shows the proportions of the various products resulting from rice milling.

CHEMICAL ANALYSES.

Table XI gives the chemical composition of the clean-rice products from the corresponding series recorded in Table VII. For comparison, these results are also calculated to a moisture-free basis

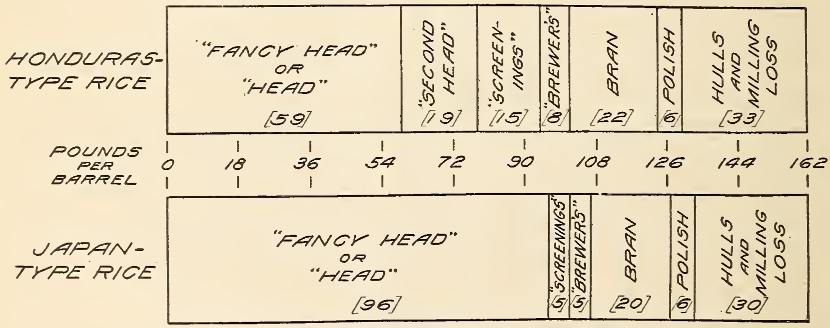

FIG. 10.—Diagram showing the average yield in pounds of cleaned rice, by grades, and of by-products obtained from the milling of a barrel of rough rice of 162 pounds.

and averages have been made for each commercial grade. The figures are practically the same as those already given for the composition of the ungraded rice from the trumbles in each corresponding series. Attention is called to the slightly smaller percentage of ash, ether extract, and crude fiber in the higher than in the lower or broken-rice grades of both the Honduras and the Japan types of rice. The protein figure for the milled rice of the Honduras type appears to be somewhat higher than that for the Japan type. This may be due to the greater length of the grain of the former and the consequent greater surface of the kernel, and therefore to the larger surface area of the protein-bearing aleurone layer. As previously stated, a considerable portion of this layer remains on the grain after milling.

TABLE XI.—*Chemical composition of samples of milled graded rice of the Honduras and Japan types in series corresponding to those in Table VII.*

Type and series.	Constituents (per cent).										
	Moisture.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.	Calculated to moisture-free basis.				
							Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.
RICE OF THE HONDURAS TYPE.											
Series 1:											
Fancy head, uncoated	12.05	0.33	0.17	0.21	7.69	1.94	0.38	0.19	0.24	8.74	2.20
Second head, uncoated	11.92	.33	.17	.26	7.31	1.94	.37	.19	.30	8.30	2.20
Screenings, uncoated	12.32	.48	.22	.25	7.31	1.91	.55	.25	.28	8.34	2.21
Brewer's rice	11.13	.65	.26	.30	7.50	1.85	.73	.29	.34	8.44	2.09
Series 2:											
Fancy head, uncoated	12.49	.31	.28	.34	8.75	1.73	.35	.32	.39	10.00	1.98
Second head, uncoated	12.01	.30	.35	.33	8.31	1.54	.34	.40	.37	9.44	1.75
Screenings, uncoated	12.75	.34	.37	.30	8.38	1.98	.39	.42	.34	9.60	2.27
Brewer's rice	12.48	.41	.21	.41	8.10	1.81	.47	.24	.47	9.26	2.07
Series 3:											
Fancy head, uncoated	12.32	.39	.24	.21	8.43	1.45	.44	.27	.27	9.61	1.65
Second head, uncoated	12.14	.44	.27	.24	8.06	1.24	.50	.31	.27	9.17	1.41
Screenings, uncoated	13.46	.60	.29	.24	7.75	1.44	.69	.33	.28	8.96	1.66
Brewer's rice	13.64	.88	.37	.34	8.12	1.54	1.02	.43	.39	9.40	1.78
Series 4:											
Fancy head, coated	11.66	.34	.23	.30	7.88	1.79	.38	.26	.34	8.92	2.03
Second head, coated	11.75	.39	.28	.33	7.81	1.95	.44	.32	.37	8.85	2.21
Screenings, coated	12.48	.46	.46	.33	7.31	1.86	.53	.53	.38	8.35	2.13
Brewer's rice	11.78	.53	.48	.43	7.50	2.03	.60	.54	.49	8.50	2.30
Average of the four series:											
Fancy head	12.13	.34	.23	.27	8.19	1.75	.39	.26	.30	9.32	1.97
Second head	11.96	.37	.27	.29	7.87	1.67	.41	.31	.33	8.94	1.89
Screenings	12.75	.47	.34	.28	7.69	1.80	.54	.38	.32	8.81	2.07
Brewer's rice	12.26	.62	.33	.37	7.81	1.81	.71	.38	.42	8.40	2.06
RICE OF THE JAPAN TYPE.											
Series 1:											
Head, coated	12.24	.34	.18	.33	6.22	1.77	.39	.20	.38	7.09	2.02
Screenings, coated	12.37	.39	.22	.37	6.25	1.69	.45	.25	.42	7.13	1.93
Brewer's rice	12.12	.39	.30	.39	6.16	1.70	.44	.34	.44	7.01	1.93
Series 2:											
Head, coated	12.17	.32	.07	.35	6.78	1.89	.36	.08	.40	7.72	2.15
Screenings, coated	12.23	.46	.13	.36	6.94	1.86	.52	.15	.41	7.91	2.12
Brewer's rice	12.70	.42	.08	.31	6.69	1.81	.48	.09	.36	7.66	2.07
Series 3:											
Head, coated	13.74	.44	.22	.18	5.88	1.45	.51	.25	.21	6.82	1.68
Screenings, coated	13.94	.50	.33	.19	6.44	1.60	.58	.38	.22	7.49	1.86
Brewer's rice	12.76	.41	.33	.24	7.00	1.40	.47	.38	.27	8.02	1.60
Average of the three series:											
Head	12.72	.37	.16	.29	6.29	1.70	.42	.18	.33	7.21	1.95
Screenings	12.85	.45	.23	.31	6.54	1.72	.52	.26	.35	7.51	1.97
Brewer's rice	12.53	.41	.24	.31	6.62	1.64	.46	.27	.36	7.56	1.87

It is evident from a study of the milling process that no important variation in chemical composition in the rice, except for the addition of a small percentage of glucose and talc, takes place after the grain leaves the brush. It is at this point that the distinction is made between coated and uncoated (erroneously called polished and unpolished) rice. The former receives an addition of a small amount of glucose and talc in the trumbles, while the latter is bagged without such a coating. The fact should be kept in mind that these two products are entirely different from the brown rice from the paddy machine, both in appearance and in chemical composition. The greater proportion of ash, ether extract, crude fiber, protein, and pentosans found in brown rice, as compared to the quantity in the corresponding milled rice, is graphically shown in figure 11, prepared from data given in Tables VII and XI.

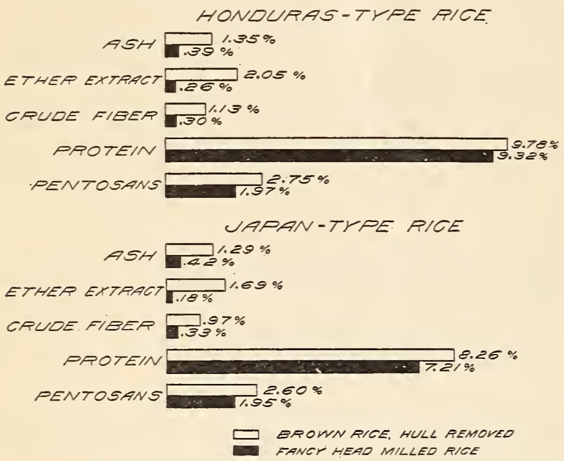

FIG. 11.—Diagram showing a comparison of the chemical composition of brown rice from the paddy machine with that of the corresponding fancy head grade of milled rice.

CHEMICAL ANALYSES OF BY-PRODUCTS.

Rice hulls are now considered of little value, if not positively harmful, as a stock feed. There is a limited market for them as a packing material at about $4 per ton, but by far the greater portion is burned to furnish power for the rice mills.

Rice bran, when fresh and free from hulls, is an excellent stock feed, but on account of its high fat content it is liable to become rancid and therefore unpalatable to cattle in warm weather. It is also frequently attacked by weevils and other insects if stored in warehouses infested by them.

Rice polish is a highly nutritious flour and is used in the United States as a stock feed. Like bran, it is susceptible to insect attack and becomes rancid in a warm climate.

The accumulation of weed seeds mixed with small amounts of rice and sweepings from the mill is generally sold locally as chicken feed. Such material may amount in exceptional cases to 15 per cent, but the usual figure is probably less than 1 per cent.

Table XII gives the chemical composition of samples of rice hulls, bran, and polish secured by the writers at various mills. Attention is called to the very high content of ash, crude fiber, and pentosans and the corresponding low figure for ether extract and protein in rice hulls.

TABLE XII.—*Chemical composition of rice hulls, bran, and polish.*

By-product, type, and grade.	Constituents (per cent).										
							Calculated to moisture-free basis.				
	Moisture.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.
Hulls:											
Honduras No. 1	6.96	20.73	0.22	42.00	1.56	20.24	22.28	0.24	45.14	1.68	21.75
Do	6.28	16.67	.78	29.98	3.56	16.11	17.79	.83	32.00	3.80	17.19
Japan No. 5	6.12	20.10	.86	36.08	2.69	18.14	21.41	.92	38.43	2.86	19.32
Average	6.45	19.17	.62	36.02	2.60	18.16	20.49	.66	38.52	2.78	19.42
Bran:											
Honduras No. 1	9.32	10.79	8.53	12.49	13.13	10.16	11.90	9.41	13.69	14.48	11.20
Do	9.91	10.37	12.77	10.92	13.69	9.74	11.51	14.17	12.12	15.19	10.81
Japan No. 1	9.39	11.33	15.13	12.54	12.81	11.40	12.50	16.70	13.84	14.14	12.58
Average	9.54	10.83	12.14	11.95	13.21	10.43	11.97	13.42	13.21	14.60	11.53
Polish:											
Honduras No. 1	7.88	5.71	10.97	3.74	12.56	4.58	6.23	11.91	4.06	13.63	4.97
Do	8.67	7.02	10.70	2.82	13.06	4.37	7.69	11.72	3.09	14.30	4.78
Japan No. 1	10.03	4.96	10.30	1.68	11.56	3.59	5.51	11.45	1.87	12.85	3.99
Japan No. 5	7.37	5.67	7.28	2.34	11.25	3.92	6.12	7.86	2.53	12.14	4.23
Average	8.49	5.84	9.81	2.65	12.11	4.12	6.38	10.73	2.89	13.23	4.50

SUMMARY.

During the past quarter of a century the important rice-growing area of the United States has shifted from the South Atlantic coast to the Gulf States west of the Mississippi River and to the prairies of Arkansas. Of the 1913 crop, valued on the farm at $22,090,000, approximately 45 per cent was grown in Louisiana, 38 per cent in Texas, and 15 per cent in Arkansas. Greatly increased production has been accomplished by the enlargement of mills and the improvement of milling methods.

The rice grain from the farm is covered with a hard, siliceous hull. The hulled grain contains a germ, or embryo, located near one end, and is covered with a light-brown bran coat which, when examined under the microscope, is found to consist of seven layers. During the process of milling, the hulls, the germ, six of the bran layers, and a portion of the seventh are removed.

A study of the evolution of rice milling in the United States shows that the farm method of pounding the grain in a wooden mortar with a pestle by hand was the earliest process. This was succeeded by milling plants employing mechanical power for operating the machinery. Mortars and pestles were enlarged, and screens, fans, polishing brushes, and hulling stones were introduced. In Louisiana small iron "plantation hullers" were used to scrape or scour off the hulls and the bran coats in a single operation.

With two or three exceptions, the 55 modern rice mills of the United States in operation in 1914 were located in Louisiana, Texas, and Arkansas. Various complex machines clean and scour the rice and prepare it for the market. Screens and fans remove the foreign material from the rough rice, which is then hulled between large revolving stones. Fans blow out the loose hulls and paddy machines separate the grain not hulled by the first treatment with the stones. Hullers, pearling cones, and brushes scour from the hulled grain the light-brown bran coat, which is separated in a powdery form through fine wire screens. In the trumbles the rice often receives a coating of glucose and talc approximating two-tenths of 1 per cent of the former and one-tenth of 1 per cent of the latter. The coating materials and the friction in the trumbles produces a bright luster. Grading the milled rice according to the size of particles is effected by shaker frames fitted with screens having perforations of various sizes; by reels, the sections of which are covered with wire of different sizes; and by cockle cylinders, which in revolving pick up the broken pieces in depressions in their inner surfaces and deposit them upon an inclosed apron suspended from the stationary axle. The various grades are bagged separately in pockets of 100 pounds each.

Excessive breakage occurs when rice of the Honduras type is milled in a "plantation huller," and the finished product may have less than 10 per cent of whole grains. The Honduras type of rice milled in a modern plant is broken to a considerable extent during the scouring process, which reduces its whole-grain content from 75 per cent as it leaves the paddy machine to 50 per cent as it leaves the brush. The Japan type of rice, on account of its shape, is broken to a less extent, and under similar conditions averages 92 per cent and 80 per cent, respectively, of whole grains.

Approximately 10 per cent of the weight of the rice kernels of both Honduras and Japan types is removed by the scouring off of bran coat and germ. In other words, the average weight per thousand kernels of rice of the Honduras type is reduced from 24.1 to 22.8 grams by the action of the hullers and pearling cone, and then to 22.1 grams by the brush. The hullers and pearling cone reduce the weight of the grain of Japan rice from 22.4 to 21.5, and the brush further reduces the weight to 20.2 grams.

Chemical analyses show that the old mortar-and-pestle mills removed a somewhat smaller proportion of ash, ether extract, and crude fiber from the grain than was the case with the "plantation huller" or than is done in the modern mill.

In the modern mill the brown rice from the paddy machine loses a considerable proportion of certain of its constituents in its passage through the scouring machines. There is thus removed from the brown rice about 70 per cent of its ash, 85 per cent of its fat or oil, 70 per cent of its crude fiber, 10 per cent of its protein, and 30 per cent of its pentosans.

The grading of milled rice is based largely on the percentage of whole grains or the size of particles. The four commercial grades of the Honduras type of rice generally made are (1) fancy head, or "head," (2) second head, (3) screenings, and (4) brewer's rice. Other grades sometimes made are extra fancy head, or triple-screened, and line rice. The whole-grain content of the fancy head grade averages about 80 per cent and its mill yield 59 pounds per barrel of rough rice. Second head, screenings, and brewer's rice are largely broken grains of different sizes, and their average yield is 19, 15, and 8 pounds, respectively.

Three commercial grades of the Japan type of rice are generally made. These are (1) fancy head, or "head," (2) screenings, and (3) brewer's rice, with mill yields approximating 96, 5, and 5 pounds per barrel, respectively. The fancy head grade averages 90 per cent of whole grains; the other grades are similar to the corresponding separations produced from the Honduras type of rice.

The mill yield of rice hulls approximates 30 pounds, of rice bran 20 pounds, and of rice polish 6 pounds per barrel of rough rice.

Chemical analyses of the several samples representing various commercial grades of rice show a slightly smaller percentage of ash, ether extract, and crude fiber in the higher than in the corresponding lower or more broken grades of both Honduras and Japan types of rice. The percentage of protein in the milled Honduras type of rice appears to be somewhat higher than that in milled Japan rice.

Rice hulls contain but little ether extract or protein, but are very high in ash, crude fiber, and pentosans. Bran and polish are rich in fat and protein, and when fresh and not adulterated with hulls are considered an excellent stock feed.

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