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Module on

MILLING OF RICE AND ITS BY- PRODUCTS

By

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Introduction:

Rice is a covered cereal. In the threshed grain (or rough rice), the kernel is enclosed in a tough siliceous hull, which renders it unsuitable for human consumption. When this hull is removed, the kernel or caryopsis, comprising the pericarp (outer bran) and the seed proper (inner bran, endosperm and germ), is known as brown rice. Brown rice is little in demand as a food. It tends to become rancid and is subjected to insect infestation. The objective of rice milling is to remove the hull, bran, and germ with minimum breakage of the starchy endosperm. The purified endosperms are marketed as white rice or polished rice, which is classified according to size as head rice (at least three- fourths of the whole endosperm) and various classes of broken rice, known as second hand, screenings, and brewer's rice, in decreasing size. There are two stages, the first being dehulling and the second whitening. Pounding (e.g; by hand using a pestle in a morter or by foot in a dheki) or the use of a steel huller of the common Engleberg type causes the grains of paddy to abrade one another. The husk is removed, and in the same operation the husks abrade the bran from the kernel. By careful pounding or use of steel hullur some separation of busk and bran can be achieved. The rubber- roll sheller and under run disk sheller split off the husk and the product, brown rice is then polished by abrasion (e.g., cylinder or cone) or self- abrasion(e.g., modified Engleberg huller). Rice husk is a valuable domestic fuel for both parboiling and cooking. It is also used as a substrate for growing mushrooms, to generate steam to run the engines of rice mills. Because the rice ash is almost pure silica, its use in glass and ceramics manufacture is being developed. Husk contains some fibre and is ground by millers to a powder for inclusion in feed for ruminants. Bran can be utilized in various ways. It is a potential source of vegetable oil. Because of its nutritional value, it is being used as feed for poultry and live stock. More stable defatted bran containing higher percentage of protein, vitamins and minerals than full fatted bran is an excellent ingredient for both food and feed. Crude bran oil of high FFA content is used for the manufacture of soap and fatty acids. Edible grade oil is produced by refining of the crude bran oil of low FFA content (about 5 %).

The Engleberg paddy huller mill

The Engleberg huller is the best known and most widely used small-scale rice mill. The initial investment and operating cost are small. It combines the two stages, dehulling and whitening in a single machine. One machine can process upto 500 kg paddy an hour. It is also easy to operate and repair. The work is done by a ribbed cylinder rotating on a horizontal axis within a cylindrical chamber, the lower half of which is formed of a screen through which fine material may pass. Rough rice is introduced at one end and passes down the gap between the rotating and the chamber wall. An adjustable steel blade determines the size of the narrowest gap through which the grain passes and thus determines the level of friction experienced. The rate of flow also serves as a means of controlling the severity of the treatment. The directions of the ribs on the central cylinder vary along its length, the major part of the length has ribs parallel to the cylinder axis but in the early stages dedicated to dehulling, they run in a diagonal curve helping to feed the stock in as well as to abrade it. The hulls removed in the initial phase help to abrade the grain surface in the latter phase. The fine materials of husk, bran, embryo, and broken endosperm are ultimately discharged through the slotted screens while the product is discharged as overtails of the screen. The product is a mixture of whole and broken grain, grain dust, bran, and husk. This is winnowed by hand or by machine. The latter usually consists of a vibrating screen, over which the rice passes while the bran/ husk mixture falls through the screen. The fine materials are used for feeding domestic stock and, as such form a valuable by- product.

The modern mill

The modern mill, developed in the 1930s, operates as a two stage process. In the first stage the paddy is dehusked. After separation from husk and unhusked paddy, the brown rice is whitened by abrasion. The principal machines used in rice milling today are under- run disk sheller, the rubber- roll husker, a paddy separator, and an abrasive whitener.

Under- run disk sheller

Under- run disk sheller consists of two grinding disks of equal diameter with surfaces partly covered with emery or carborandum. Two disks are mounted horizontally, the upper one remains stationary while the lower one rotates. Corresponding rings on the outer region of both disks clear each other by a small adjustable gap, through which the rough rice passes, having being fed in from a central hopper.

Optimal hulling results from a clearance of slightly more than half the grain length. Approximately 25% of the grains escape hulling, owing to their small size, and have to be returned for retreatment, not in the same machine but in one with a smaller gap. Such hullers lead to more breakage of grains than rubber roller type.

Rubber roll hullers

Rubber roll hullers are widely used in modern rice mills. A pair of rolls of equal diameter, run in a similar fashion to the steel rolls of a flour mill, in that both rolls of the pair turn on a horizontal axis, towards the nip, into which the rough rice is fed. Differential speed of the two rolls causes disengagement of the hulls. Before passing to the husker, the paddy must, of course, be clean, free from straw, chaff, sacking, dirt, stones, and metal. The stones and metal can destroy the rubber on the rollers, and in addition to destoners mills have a magnet to remove tramp steel, usually in the form of nuts and bolts fallen from conveyers. Rubber rolls cause less mechanical damage and improve stability against rancidity.

Seperation

After husking, the paddy and products are separated. The first stage is to remove the light weight husk in a current of air. The second is to separate brown rice from unhusked paddy by a paddy separator. The machine is usually made of wood. It consists of the following main parts: the feed box, the table enclosing the compartments, the collecting troughs for the separated products and their discharge outlets, and the frame work carrying the table, the reciprocating movement drive mechanisms and speed variator.

The main part of the separator is the oscillating compartment assembly where the separation of paddy and husked rice takes place. The table is divided cross- wise into several compartments the shapes of which form a zig zag. The number of compartments varies from 5-8 depending on the capacity. The bottom of these compartments is slightly inclined. The whole assembly consists of one, two, three or four disks.

The mixture of husked and unhusked grains is fed to the compartments in equal quantities, through the hopper. The table moves forward and backward horizontally. The movement for thrusting the grains towards the upper edge of the slant table is obtained by means of eccentric motion. Normally the stroke length is about 20 cm and not adjustable. The grains cross- wise inside the compartment and alternatively hit the zig zag walls. These walls are oblique and the grains rebound obliquely. The grains receive the oblique upward thrust. The husked paddy moves down slowly where as the unhusked paddy moves up the inclined plane. The two components are thus separated and discharged from the two opposite sides.

Whitening

The term whitening refers to the operation of removal of germ, pericarp, tegmen and aleurone layers from husked rice kernals. There are three major kinds of whitening machines used in the modern rice processing industry. These are:

1) Vertical abrasive whitening cone,

2) Horizontal abrasive whitening roll and

3) Horizontal metallic friction type roll.

Vertical abrasive whitening or pearling cone

The machine consists of a rotating vertical conical cast iron cylinder covered with an abrasive material. The entire rotating cone is encased within a fixed perforated metal sheet known as crib. The gap between the abrasive surface and the crib is about 10 mm. It is provided with rubber brakes, placed vertically and spaced equally which protrude into the gap between the abrasive cone and the crib. The clearance between the rubber brake and crib is about 2-3 mm. The pressure inside the whitening chamber can be adjusted by pushing in or out the rubber brakes.

The husked rice enters the gap and is dragged along by the rough surface of the rotating cone. The rubber brakes tend to stop it and cause it to pile up against their side. While pressed up against the brakes, the grains under go a strong swirling and revolving movement because of their oval shape and smooth surface. Each grain is scoured by the abrasive surface of the cone. It also rubs against the surrounding grains and the rough lining of the crib as well. The grains meet almost same conditions all the way round the cone until they sink lower and lower by gravity and are finally discharged at the bottom of the cone. The bran is finally ground due to scouring and rubbing and escapes through the lining of the crib and regularly removed.

Horizontal rice whitening machine

To remove bran layers from the husked rice, a combination of two different types of whitening machines, namely grinding type and friction type are employed. As the surface of husked rice is smooth and slippery, the grinding type of machine is used at the initial stage of whitening in order to shave and grind the bran layer into smaller particles and impart roughness to the grain surface as well by the thrust and frictional force of a revolving abrasive roll. The friction type machine is employed subsequently to peel of the remaining bran layer easily by the friction between rice grains by the high pressure created by a rotating ribbed steel roll. If the smooth husked rice kernels were directly whitened by the friction type machine only, it would require much higher pressure and power for whitening. The yield of brokens would also be more. In general, the first and second stage of whitening operations are done by the grinding type machines and the last stage of whitening is done by the frictional type machine. Therefore, the friction type machine is used for giving uniform polish and surface finish to the rice. These machines are arranged in series so that the rice is whitened successively.

Friction type whitening machine

The purpose of the friction type whitener is to remove remaining bran easily and uniformly from partially whitened rice produced by the horizontal abrasive whiteners when rice is allowed to enter into the space between the rotating steel roller and the hexagonal screen of the whitener, mutual rubbing of the rice kernels takes place under pressure.

The peripheral speed of the steel roller is below 300/min. The speed between the hexagonal screen and steel roller is different at different points. Mutual rubbing of grain occurs at a position where the annular space is narrow, and bran is removed from the rice kernel. After passing through the narrow gap between extruding part of the roller and screen, the grain enters into the wider space where it receives a strong air stream which facilitates the separation of bran from the grain. It also helps in discharging bran through the slots of the hexagonal screen. The whitened rice produced by this machine is free from bran, slightly shining and cool. The inner surface of the slotted hexagonal screen has a number of small projections which enhance rubbing action. Pressure is applied by the resistance plate with weight. Whitening is mainly performed by mutual rubbing of grains and partly by rubbing of grain with the screen. Higher pressure is necessary to accelerate the whitening.

Polishing

The rice emerging from the whitening process has the outer layers of bran removed but the inner layers remain. The remaining fragments are removed by the process known as polishing or refining. In conventional rice mills polishers are like whitening cones, but instead of abrasive coverings, the cone is covered with many leather strips. No rubber brakes are applied.

Polishing extends the storage life of the product as the aleurone layer is removed, thus reducing the tendency for oxidative rancidity to occur in that high-oil tissue.

By- products of rice milling

Rice husk and rice bran are the two main by-products of rice milling industry.

Husk

There are many suggested uses for husk and the ash made by burning it. In traditional societies rice husk is a valuable domestic fuel for both parboiling and cooking. The ash is spread on the fields as fertilizer. It is also used as a substrate for growing mushrooms. For more than 100 years husk has been used to generate steam to run the engines of rice mills, including their parboiling plants and dryers. Rice husk is unique in its extremely high silica content. The ash made by burning husk consists mainly of silica (silicon dioxide, more than 95%) in an amorphous form. Treatment with sodium hydroxide yields sodium silicate, an important industrial fire brick. Because the ash is almost pure silica, its use in glass and ceramics manufacture is being developed. Husk contains some fibre and is ground by millers to a powder for inclusion in feed for ruminants. Husk is also a useful addition to balanced rations low in roughage.

Bran

Rice bran consists of 12 % to 15% protein, 15% to 20% lipids, 40% to 50 % available carbohydrates, 7% to 11% crude fiber, and 6% to 9% crude ash. Bran can be utilized in various ways. It is a potential source of vegetable oil. Because of its nutritional value, it is being used as feed for poultry and live stock. More stable defatted bran containing higher percentage of protein, vitamins and minerals than full fatted bran is an excellent ingredient for both food and feed. Crude bran oil of high FFA content is used for the manufacture of soap and fatty acids. Edible grade oil is produced by refining of the crude bran oil of low FFA content (about 5 %). In addition, tocopherol and waxes of high melting point suitable for various industrial purposes are the by- products of the bran oil refining industry. Unfortunately, when the bran is produced in the mill, the enzymes in the germ are released and start to break down the oil into free fatty acids and oxidised fats, which are rancid. The bran must be stabilized as quickly as possible after production to prevent rancidity. The standard method is to pass the bran through a screw conveyer equipped with a steam jacket. Recently, extrusion- cooking has proved very successful and cheaper.

Oil extraction methods can be divided into two major groups: mechanical method and solvent extraction method. In mechanical method either hydraulic press or oil expeller is used to press oil out of the bran which has already been processed by steaming and drying. The high pressure employed is in the range of 70- 280 kg / cm^2. But the output of oil is low compared to the solvent extraction method. In solvent extraction method usually n-hexane is used. This method is now universally used mainly due to high oil output. Three systems of solvent extraction operations are in use, namely batch, semi continuous and continuous systems. The batch type is popular due to its simplicity in operation and low cost of installation. Pretreatment of bran prior to extraction is an essential step for either batch or continuous system. Pretreatment consists of either direct steaming and drying of bran or drying of bran alone at 90^0- 100^0c to 6-8 % moisture content. Pretreatment of bran reduces amount of fines and moisture content and thereby increases the particle sizes, aids the release of oil from bran, imparts hardening effect to bran particles for better extractability, lower filteration time and it eliminates the problem of fines. Without pretreatment, the fines would create problems like resistance to percolation of oil, channelling resulting in longer steaming time for the desolventization of meal and low rate of extracibility. Because of the presence of free fatty acids, gums, wax, colouring and odouring matters etc., the rice bran oil is the most difficult oil among all vegetable oils to refine.

Several patented methods are available for the refining process. Generally the following steps are adopted:

1) Preliminary dewaxing and degumming process to remove hard wax, gums, mucilages and some other impurities.
2) Neutralization process for the removal of free fatty acids.
3) Decolourizing process for the removal of coloring matters.
4) Deodorization process for the removal of odorous matters and unsaponifiable matters.
5) Winterization operation for the removal of soft wax.

A simplified flow diagram for bran extraction is shown in Fig. 1.

Rice bran

□

Cleaning

□

Sterilize/Stabilize (Steam; cook-extrude)

□

Dry if necessary

□

Store and Transport

□

Stable bran

□ **n-hexane**

Oil extraction

□

De-waxing

□ **Degumming agent**

Degumming

□ **Alkali (soda)**

Removal of free fatty acids

□**Kaolin + Charcoal**

Bleaching

□**Live steam**

Deodorization

□

Chilling

☐

Packed oil

Fig. 1: Flow sheet for rice bran oil extraction

Rice brokens

Milling of rice gives a high proportion of broken grains. These have been used for food, often merely by making gruel or porridge, plain or fermented. It can also be used in the manufacture of pasta, and fermented products.

Rice pasta

Among people of the Far East, broken rice is often used to make noodles (rice pasta).The first step is to mill the broken rice to flour. This is then processed in much the same as when Italian pasta is made from durum wheat. The principle difference is that the rice contains no gluten, which in the case of pasta, acts as the binding agent when the dough is extruded. For rice pregelatinized starch is used. The dough is extruded through a metal die to give pasta of circular cross section. Flat pastas are also used and can be extruded or made simply by rolling the sheets of dough and cutting it into strips.

Fermented Products:

Idli and Dosa:

Idli and dosa are common foods in south India. Idli is made by soaking rice and a pulse (black gram, Bengal gram or other legume) separately overnight and then, after drying, grinding in a stone mill. The rice is coarsely ground whereas the gram is finely ground. The two slurries are combined and the thick batter is stirred, salted and possibly other flavourings added, and the batter is left overnight to ferment. Inherent microorganisms are usually enough to effect the lactic fermentation, but sometimes a barm is used. Several microorganisms have been found in the idli batter, of which *Leuconostic mesenteroids* produces the leavening and, with *Streptococcus faecalis*, produce the acidity. The batter is then steamed in small cups for about ten minutes. Idli cakes are soft , spongy, slightly acidic and easily digestible. The ratio of rice/ legume can vary from 25 % to 75 %.

Dosa is a thin, crisp, fried pan cake- like staple food of South India eaten mainly as a breakfast food but becoming popular as a snack food throughout India. It is prepared by soaking 1-3 parts of rice and one part of black gram dal or yellow lentils in water for 4-6 h at ambient temperature, grinding to a fine paste by adding 2- 2.5 parts water and mixing the two together to make a free running batter. The batter mixture is then allowed to ferment overnight for 12- 24 h after the addition of about 1% salt, by means of the natural microflora. About 60-80 ml of the batter is then spread on hot greasy griddle for a few minutes where it assumes the form of a crisp pancake.

Miso

Miso is a fermented paste used to season other foods. It is made by a complex and variable process in which soyabean is soaked and boiled till soft and mixed with fermented rice (Koji). This is made from steamed rice inoculated with a source of *Aspergillus oryzae* (barm, preferment). Fermentation is considered sufficient when every rice grain is covered with mold. The koji rice is removed from the fermenter and mixed well with the salt to stop any further development of the mold.

The next fermentation is carried out under anaerobic condition by yeast and bacteria. Cooked soyabeans are slightly mashed and mixed with the salty koji and then inoculated with a starter containing pure culture of yeast and bacteria. The well blended mixture, now known as green miso is tightly packed into the vat or tank for fermentation. At the end of fermentation, the mass is kept at room temperature for about 2 weeks to ripen. The aged product is then blended, mashed, pasteurized and packed.

Sake

Sake is the traditional Japanese rice wine. Koji is used as a culture of *Aspergillus oryzae.* The Koji is mixed with water, and *Lactobacillus* is added. The combination of microorganisms breaks down both starch and protein, which will yield a well flavoured, sweet/ sour product. To this is added sake yeast, which is a variety of *Saccharomyces cerevisiae*. This starter is added to a mash of steamed rice and water. Fermentation is at a lowered temperature with no attempt to exclude extraneous microorganisms and lasts for 3 to 4 weeks, by the end of which the temperature has been lowered to 10 ^{0}C. Much of the final parts of the process resemble lager brewing- filtration, pasteurization, etc. The product is slightly sweet, acid, and has a high ethanol content- upto 19 %.

Rice Vinegar

Rice vinegar is made from the Koji and rice mash, using first *S. cerevisiae* and then *Acetobacter spp*. The whole fermentation is carried out at 30 ^{0}C. Sterilization of the mash is desirable to eliminate lactic bacteria. The acetic acid so produced may be distilled and diluted with pure water to give "chemical" vinegar, suitable for cheap manufactured pickles.