By-Products of Rice Milling
“Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances.”

— Indira Gandhi
## BY-PRODUCTS OF RICE MILLING

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Processing of paddy results in a number of useful by-products such as husk, bran, germ and brokens (large and small). Husk constitutes about 20-22% by weight of grain. For the health and economic viability of any industry, utilization of its by-products into value added products is very important. Due to persistent efforts of scientists and technologists, all the above by-products have many uses and the products are in great demand.

**Unit 12** describes the various uses of broken rice which is an important by-product of the process. We discuss the grading of brokens, separation and purification of germ, conversion of brokens into rice flours and semolina along with extraction of starch in the unit. Apart from above, extraction of starch, fermentation of brokens for alcohol production and preparation of fermented food products such as idli and dosa are also discussed.

**Unit 13** deals with Rice Bran the most important by-product of milling process and its various uses as human food and animal feed. We also discuss the processing of rice bran for protein extraction. Extraction of rice bran oil, refining of rice bran oil and the uses of various products of refining are also discussed in the unit.

**Unit 14** describes the structure, composition and properties of rice husk the outer cover of paddy grain. We also explain the use of husk as fuel for different purposes including its use in boilers for generation of steam which is essentially required for the parboiling and drying of paddy before milling. Gasification of rice husk and its use for power generation as well as use of husk ash for different purposes is also discussed in the unit.
UNIT 12 RICE BROKENs

Structure

12.0 Objectives
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  12.2.1 Equipment for the Grading of Brokens
12.3 Separation and Purification of Rice Germ
  12.3.1 Separation
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12.0 OBJECTIVES

After reading this unit, you should be able to:

- know the meaning of rice brokens;
- learn regarding equipment for grading of brokens, separation and purification of germ;
- get information on value added products produced from brokens;
- explain steps for production of various rice brokens based items;
- know the important considerations in the process technology; and
- learn regarding changes in nutrition values of the product.
12.1 INTRODUCTION

Milling of paddy is the main step in paddy processing. It consists of removing the husk and outer bran layers to produce acceptable white rice. The final white rice contain broken grains (rice kernels less than 3/4\(^{th}\) of the size of the whole grain) varying between 30 and 50% depending upon the pre-and post harvest operating conditions, paddy variety and the type of milling machinery. Brokens not only reduce rice yield but lead to economic loss as well, due to its very low selling price. Leaving aside a permissible limit of mixing 18 to 25% of these broken grains in milled rice, it may still be considered an undesirable loss to the nation.

In India, the selling price of broken rice is about 1/3\(^{rd}\) the price of whole rice and it is largely used as feed, brewing adjunct and as raw material for preparation of breakfast foods, such as idli, dosa etc. However considerable potential and need still remain for development of some value added products using this relatively cheaper by-product of the rice milling industry. Even though modern rice milling systems are very efficient, some rice kernels inevitably yield high percentage of brokens sometime during the milling process. After the paddy is milled, it is necessary to separate broken kernels from the whole grains. Depending upon the level of brokens allowed by the customer’s specification, these broken grains may be blended in a precise ratio with whole grain kernels to maximize the profitability of the mill.

12.2 GRADING OF BROKENS

12.2.1 Equipment for the Grading of Brokens

12.2.1.1 High capacity grading sifter

The grading sifter uses a rotary or vibratory motion to expose grains to a surface that is made of perforated metal or woven wire cloth. Grains shorter than a certain size fall through the openings in the cloth, while longer kernels remain on the sifting surface.

12.2.1.2 Indented Cylinder Grader

In this machine, rice is placed inside a cylinder that has indentations punched into its inner surface. As the cylinder rotates, rice kernels are lifted by the indentations. Depending upon the length of the individual grains, they fall from the indentations at different points. The broken grains, which are shorter than the unbroken kernels, remain in the cylinder longer, and are lifted to greater heights. An adjustable collecting trough is positioned so as to select the size and amount of brokens to be removed.

12.2.1.3 Electrical Sorting

Modern rice millers are able to remove almost all foreign objects from paddy during the milling process through magnets and mechanical means. But there may be some nonmagnetic objects that are similar in size and density to whole or broken rice kernels, and these are very difficult to remove using mechanical means.

To remove such foreign objects, it is common to use devices that can differentiate between rice kernels and the foreign objects on the basis of their appearance. These devices are commonly referred to as “Colour Sorters”.

12.2.1.4 Optical Sorter

In this machine, rice kernels are made to fall at a specific speed down a path, causing them to pass through the focal point of a camera. The camera gathers light, which is reflected from an adjustable plate known as the “Background.” A photoelectric sensor then converts the gathered light into an electrical signal, the magnitude of which is
proportional to the intensity of the reflected light. Any grain that appears darker than the background results in a negative voltage. A trigger mechanism, called the “sensitivity control,” allows the operator to define how dark an object must be in order to be considered “objectionable.” A microprocessor then analyzes the signal, compares it to the magnitude that is considered objectionable, and if appropriate, sends a signal to an electromagnetic valve. The valve is energized, opens, and allows a blast of compressed air to escape. The compressed-air blast deflects the undesirable kernel from the rice stream, removing it from the finished product.

Check Your Progress 1

Note: a) Use the spaces given below for your answers.
    b) Check your answers with those given at the end of the unit.

1. Describe broken rice.

2. What are the important parameters which affect the level of brokens in milled rice?

3. What is the permissible limit of brokens in milled rice?

4. List the equipment for grading of brokens.

5. What is the main principle of “Colour Sorter”?

6. Describe the working of Optical Sorter.
12.3 SEPARATION AND PURIFICATION OF RICE GERM

Rice germ is embryo-the rudimentary form of future plant. It is extremely small and is located on the ventral side of the caryopsis. It has 2 to 3 % weight of brown rice. The embryo has 4.8 to 7.4 % pentosans, 4% cellulose, 3 to 6 % lignin, 11.6% reducing sugar, 2.1% non-reducing sugar and 0.8% phytin phosphorous. Albumin and globulin are concentrated in the germ. The protein efficiency ratio of gerin is 2.59 and biological value (BV) 78. The germ contains 4.6% of free amino acids in its protein. Rice germ is high in phosphorous and low in calcium; it contains somewhat more sodium and much less silica. Germ is also rich in vitamins. Purified germ has a bulk density of 0.51 g/cc.

12.3.1 Separation

To maintain the nutritive value of milled rice, germ-remained (milled) rice- in which germ is remained in more than 80% of the grain- has been produced in many commercial mills in Japan. In other countries germ forms an integral part of bran in the mill-stream. Because of the embedding of germ with scutellum and endosperm during parboiling, most of the germ is retained in the milled parboiled rice.

12.3.1.1 Laboratory-level Separation of Germ

50 gm bran (bran and germ) previously sifted is led on the screen. Air is passed through it upwards. When pressure, as indicated in the manometer, is about 2 cm H$_2$O column, light impurities are removed. When pressure is about 10 cm H$_2$O column, rice germ is aspirated, leaving on the screen brokens, stones, and heavy impurities.

12.3.1.2 Pneumatic Rice Germ Separator

The horizontal set up consists of a blower coupled to an AC motor, conveyance pipe, feeding hopper, mixing nozzle, expansion chamber and cyclone separator. The vertical set up consists of a blower coupled to an AC motor, conveyance pipe with feed back arrangement, feeding hopper, mixing nozzle, settling chamber and cyclone separator. It has separation efficiency of 61%.

12.3.1.3 Degermer

A laboratory level batch degermer is in operation at the paddy processing research centre (PPRC) Tiruvarur, India. It consists of a main shaft with 4 metal prongs. When the brown rice is fed into the perforated chamber, the germ is removed due to the friction caused between the grains. The germ recovery is 90 to 95%. During this process, about 2.5 % bran also is removed along with germ.

12.3.2 Purification

The germ coming out the sifter still contains bran, husk, brokens and other impurities. Purification is carried out by sieving through a shaking device comprising the 3 sieves: mesh number 20 (ASTM) (0.8 mm $\phi$) for separating residual bran; mesh 1.5 mm $\phi$ for separating germ and mesh 2 mm $\phi$, for separating rice powder.

After sieving, the air blowing upward further cleans the germ fraction. Air speed in the aspiration system may vary greatly, depending on the physical characteristics of the byproducts.
12.4 RICE FLOURS AND SEMOLINA

In the wheat industry, milling always produces flour. In the rice industry, the terminology differs. Milling usually refers to the removal of bran for producing polished rice, and grinding broken or polished rice produces rice flour. The applications of rice flour include traditional Asian foods and baked goods, many of which have now spread around the world. Rice flour can also be used to produce gluten-free rice bread for gluten-sensitive individuals and is typically used in baby foods. Thailand, a major exporter of rice flour, offers a price near the world average. China, the principal rice producer, offers the lowest price for rice flour in the market. The world average price of rice flour showed a steady growth from 1990 to 2000, which indicates a growing market for rice flour.

Based on starch type, there are two primary types of commercial rice flours available in the market. The first is produced from glutinous or sweet rice and is used for making many types of oriental snack foods, as well as a thickening agent in white sauces, gravies, puddings, and prepared frozen foods. It can prevent liquid separation that occurs when some food products are frozen, stored, and subsequently thawed. The other major type of rice flour is prepared from broken grains of non-glutinous raw or parboiled rice. The rice flour made from parboiled rice is essentially pre-cooked rice flour. Rice flour differs from wheat flour in baking properties because rice flour does not contain gluten, and its dough does not retain gases generated during baking. Gluten in wheat flour provides elasticity in the dough to allow retention of CO₂ gas generated during baking. Rice flours can be used in a wide range of applications including ready-to-eat breakfast cereals, crispy rice for candies and snacks, infant cereals, French-fry coatings, extender in
By-Products of Rice Milling

Powdered cheeses and powdered sugars, waffle and pancake mixes and sauces, soups and gravies. These industrial applications, combined with household needs, are sufficient to sustain a market for rice flour production.

Rice flour is often used as an ingredient in cereals made from other grains. In addition to providing a more tender bite, rice flour in flaked cereals improves flake expansion. Waxy rice flour improves bowl life, because the higher amylo-pectin level produces a more hydrophobic gel. Extruded cereals formulated with other grains often include rice flour to improve crispiness and expansion, as well as reduce breakage. Pre gelatinized rice flour can also be used as a functional aid, holding extra water in the product for more expansion and absorbing water faster in the extrusion process, which decreases dwell time.

Rice flour is often used as an ingredient in cracker and chips for many of the same reasons that it is used in multi-grain breakfast cereals: to control moisture, bite, texture and flow in extruders. Long grain rice flour increases crispness, whereas pre-gelatinized or partially gelatinized rice flour improves water absorption and dough sheeting. Chips made from rice flour absorb less fat during frying than those made from potatoes. In addition, baked or fried chips with 5 to 10 % waxy rice flour experience less breakage.

12.4.1 Properties of Rice Flours

Rice flours made from long, medium and short grain and waxy rice are available for commercial and home usage. There are varietal differences in protein, lipid, starch content and by amylose to amylo-pectin ratio in the starch. Differences in chemical composition between rice varieties contribute to the diversity of chemical and physical properties of various rice products. The characteristics of rice flour can be measured objectively by such properties as their viscosity behavior when heated with water, starch gelatinization temperatures, birefringence end point temperature, and water absorption capacity.

12.4.2 Preparation of Rice Flour

Three methods, namely wet, semi-dry, and dry milling are used to prepare rice flour as illustrated in Figure 12.1. Soaking, milling, drying and regrinding are involved in wet milling. Usually rice is soaked in water for more than 4 hours, drained, and ground by a stone mill with water (3 to 5 times the weight of rice). The key purpose of wet milling is to prepare flour while causing only minimal damage to the starch. Damage can be reduced by the cooling and lubricating effects of water. After milling, excess water is removed by drying, and the flour is then gently regrind to prepare the wet-milled flour. This flour is generally used for products such as Japanese cake, rice crackers, Taiwanese cakes, rice noodles, Filipino rice cakes and Indian fermented foods such as idli, dosa etc. The treatment of waste water becomes an issue in most countries.

In semi dry milling, rice is soaked, drained and ground by using a stamp or pinmill without adding any water. Because no excess water is used, the disposal of waste water is eliminated. In general, the applications of semi dry milled flour are similar to those for wet milled flour.

In dry milling, cleaned rice can be directly ground to different sizes by various mills. Different mills (including rolling, pounding, shock, stone, and lateral steel) can be used to prepare rice flour without generating any waste water, but the starch shows more damage, which influences the applications of the rice flour. The particle size of the rice flour plays a key role in the flour properties. Dry milled rice flours usually have the same protein content as does the parent rice and are used for baked products, baby foods, extrusion cooked products and in high protein flour.

12.4.3 High protein Rice Flour

High protein fractions can be used for the nutritional supplements in baby foods or other products, such as instant milk, gruel, and puddings. These foods provide needed protein in the diets of young children in rice eating countries.
12.4.4 Brown Rice Flour

Health conscious consumers are becoming more interested in brown rice flour because of its nutritional value. This flour is prepared via different milling methods, using rough rice as the starting material. The presence of bran imparts a different flavor and chewy texture to products. Unfortunately, brown rice flour has limited shelf-life stability due to the lipase activity initiated in the bran layers during dehusking. The lipid components are enzymatically hydrolyzed, freeing fatty acids and causing rancidity. The rancidity can be minimized when the enzymes are inactivated.

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**Check Your Progress 3**

**Note:**

a) Use the spaces given below for your answers.

b) Check your answers with those given at the end of the unit.

1. What is the difference in the terminology of “milling” in wheat and rice milling industry?

2. List the applications of rice flour in food industry.

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3. What are the primary types of commercial rice flours available in the market? Mention their uses.

4. How do you differentiate rice and wheat flour based on properties?

5. List the industrial applications of rice flour.

6. What is the main difference between rice chips and potato chips?

7. List the properties to measure the characteristics of rice flour.

8. What are the methods available for making rice flour? Indicate main unit operations in the process.

9. Describe wet milling and uses of wet mill flour.

10. What are the advantages and disadvantages of dry milling?
11. List the uses of dry milled flour.

12. What are the main features of high protein rice flour?

13. List the main disadvantages with brown rice flour.

12.5 EXTRACTION OF STARCH

12.5.1 Commercial Method

Commercial preparation of starch from rice is limited owing to the high cost of brewer’s rice relative to other cereals and tubers. Sodium hydroxide is used for purifying milled rice starch because at least 80% of the protein of milled rice is alkali-soluble protein (glutelin). The process consists of steeping broken rice in 0.3-0.5% sodium hydroxide solution, wet milling the steeped grain, removal of cell walls, extraction of the protein with sodium hydroxide solution, washing, and drying. Trash and dirt are removed by preliminary cleaning. Steeping softens the grain and aids in extracting the protein. Steeping temperature varies from room temperature to 50 °C, and the steeping period is usually 24 hr. Wet grinding is preferred to dry grinding, as starch damage is more extensive in dry milling, resulting in greater starch losses through dissolution in alkali. The steeped rice is usually ground or wet milled in pin mills, hammer mills, or stone-mill disintegrators in the presence of sodium hydroxide solution. The starch suspension is then stored for 10-24 hr, after which fiber is removed by passing the suspension through screens, and the starch is collected by centrifugation, washed with water, and dried in a dryer. Usually only one extraction is made, as 97% of the protein of milled rice flour is extracted in 3-6 h with 0.4% sodium hydroxide.

12.5.2 Laboratory Methods

The most common laboratory method of preparing rice starch is by alkali extraction of the protein using 0.2-0.3% sodium hydroxide solution. Milled rice or broken is steeped in 5-6 volumes of 0.2-0.3% sodium hydroxide solution at 25 °C for 24 h to soften the endosperms. The steep liquor is drained off, and the endosperms are pressed and ground lightly in successive small fractions with a mortar and pestle. The slurry is then diluted to the original volume with 0.2-0.3% sodium hydroxide. The mixture is stirred for 10 min and allowed to settle overnight. The cloudy supernatant is drained off, and the sediment is diluted to the original volume with sodium hydroxide solution. The process is repeated until the supernatant becomes clear and gives a negative reaction to the biuret test for protein (10-20 days). Starch is suspended in distilled water, passed through a 100-200 mesh nylon cloth, and repeatedly washed with water until the supernatant no longer shows any pink color with phenolphthalein. The starch is collected by sedimentation or centrifugation, and the white middle portion is collected (thin dark surface and bottom layers are discarded) and air-dried. The whole process takes 20-30 days.
Improvements in the method include homogenization of steeped grain in a Waring blender and passing the resulting mixture through a 200 mesh sieve before the sodium hydroxide treatment. Continuous shaking for 3-6 h is sufficient for alkali extraction of protein and hastens the preparation of starch. Lower alkali concentrations are ineffective for complete extraction of proteins and starch lipids.

Another commonly used method involves treatment with a detergent solution (1-2% dodecyl benzene sulfonate (DOBS) to which 0.2% sodium sulfite is added just before use). Milled rice is steeped in 3-4 volumes of the detergent solution for 24 to 48 h. The supernatant is decanted off, and the residue is crushed in a mortar and pestle to pulverize the milled rice, adding detergent solution as needed. The slurry is passed through a 200-mesh cloth or sieve, and the large particles are ground further in a mortar and pestle. Low-speed grinding of the steeped grain in water may also be employed. The sieved starch is then shaken with 5 volumes of fresh detergent solution for 6 h, and the supernatant is removed by centrifugation. This treatment is repeated 3-4 times to remove any trace of protein and fat, and the purified starch is then washed repeatedly with distilled water until the washing becomes negative for sulfate. The starch is then again washed two to three more times with water. The purified starch is collected after discarding the thin layer of darker starch at the surface and bottom and air-dried. Yields are 33-50% of milled rice.

Ultrasonication has been employed for purifying rice starch. About 5 g of milled rice powder suspended in 45 ml of distilled water in a test tube is subjected to 10 kHz for 10-20 min. The homogenate is filtered through a 200 mesh sieve, and the filtrate is allowed to settle. After scraping off the dark upper layer, the starch is collected, washed, and air-dried.

12.5.3 Physico-Chemical Properties of Rice Starch

Rice has one of the smallest starch granules of the cereal starches, varying in size from 3 to 10 μm in the mature grain. Mean granule size varies from 4 to 6 μm. Starch granules of rice are compound, and they are polyhedral or pentagonal dodecahedron. As with other starches, waxy starch granules tend to have lower density than non-waxy granules. Final gelatinization or birefringence end-point temperature (BEPT) of rice starch varies widely among rice varieties and is classified in rice as low (58°C-69.5°C), intermediate (70°C-74°C), and high (74.5-79°C).

12.5.4 Uses of Rice Starch

The widespread use of rice starch is currently limited by its higher price relative to corn, wheat, and potato starches. Principal uses of rice starch as (a) a cosmetic dusting powder, (b) a laundry stiffening agent in the cold-starching of fabrics, and (c) a “custard” or pudding starch. In the European Economic Community, rice starch (low-amylose) is used in baby foods, in specific paper and photographic paper powder, and in the laundry industry.

Check Your Progress 4

Note: a) Use the spaces given below for your answers.
   b) Check your answers with those given at the end of the unit.

1. What is the main chemical used in commercial method of starch extraction? Mention its concentration.
2. What are the important operations in commercial method of starch extraction?

3. Why do you prefer wet milling than dry milling in commercial method of starch extraction?

4. What are the operating parameters in commercial method of starch extraction?

5. What are the important operations in laboratory method of starch extraction?

6. What is the improved method of laboratory method of starch extraction?

7. State the reason to use higher alkali concentration in starch extraction.

8. What is the detergent solution used in starch extraction? Mention its concentration.

9. What is the concentration of sodium hydroxide to give highest protein extraction of 97%?
10. Describe ultrasonication for purifying rice starch.

11. What are the physico-chemical properties of rice starch?

12. List the principal uses of starch.

12.6 CANNED RICE

A numerous canned products that contain rice include soups and “dinners”, baby foods, plain and flavoured cooked rice, and of course, milky rice pudding. The most suitable varieties for most of these are the long grain high amylose type. The rice should, for preference, have been parboiled. It provides a high degree of grain stability throughout the canning process, which is essential in this product. The most well-known and successful product is canned rice pudding.

Canned rice fall into two categories: wet pack and dry pack. A product, in which there is excess of liquid, such as in soup media, is termed wet pack. Proper density is the prime objective with these types of products. The rice is precooked or blanched sufficiently to promote buoyancy in the product and prevent settling and matting. This washing process removes excess surface starch. The rice is put into cans together with the sauce. The cans are sealed under vacuum and then retorted to sterilize the product.

A commercial process has been evaluated for canned white rice packed in 301 x 411 cans with a fill weight of 340 g rice (55-60% moisture) for each can. The initial temperature is 40 °C and the come up time 10-15 minutes. The recommended processing time at 118.3 °C is 55 minutes. The equivalent sterilization value at 121 °C is 13.29 minutes. The variety has a strong influence on the quality of canned rice.

Check Your Progress 5

Note: a) Use the spaces given below for your answers.
    b) Check your answer with those given at the end of the unit.

1. State the reason to use parboiled rice for canning.

2. What are the canned rice products available in the market?
3. Describe wet pack canned rice.

4. Describe commercial process of canning rice.

12.7 FERMENTATION OF BROKENS FOR ALCOHOL PRODUCTION

Starch is the major constituent of milled rice and makes up 90% of the milled rice in dry weight. Milled rice contains 0.37 to 0.53% total free sugars. Rice is widely used in the world for the production of alcoholic beverages because of its low protein and lipid contents. Rice is the main ingredient, often the sole cereal source, in such beverages as sake in Japan, shaoshin-chu in China, Madhu & Ruhi in India and miscellaneous beverages in eastern Asia. Rice is also used as adjunct in the production of other alcoholic beverages, such as beer.

Rice is usually used for brewing in the form of rice grits (or) broken rice, which is obtained as a by-product of rice milling industry. The rice used for beer brewing consists of almost-pure fragments of endosperm that contain starch exclusively.

12.7.1 Indian Madhu

Madhu is a primitive, low-alcohol rice wine in which raw rice soaked in water is the substrate. Madhu is a tribal drink produced and consumed primarily in the Nagaland and eastern hill regions of India. It is salted to taste and is used as an early morning meal.

Production: A flow sheet of the production of Madhu is given in Figure 12.2. During fermentation, the mixture froths and slight liquefaction of the rice starch occurs.

Microbiological and biochemical changes: Molds of genera Mucor and Rhizopus are present, together with yeasts and lactic acid bacteria. Some of the starch is hydrolyzed to sugars which are fermented to alcohol and lactic acid. The final pH is 3.8 to 4.5.

Soak 10 kg raw rice in cold water (2hr)

Drain and grind rice to a paste

Slurry with hot water

Add 15 litre cool water and yeast

Ferment 2-3 days (winter), 1 day (summer)

Madhu

Fig. 12.2: Production of Indian Madhu
12.7.2 Indian Ruhi

Description and patterns of consumption: Ruhi is a strongly alcoholic beverage made by fermentation of boiled rice. It is a special drink produced primarily by tribal people in Nagaland and eastern hill regions of India.

Steps in preparation: A flow sheet of ruhi production is given in Figure 12.3. The boiled rice is spread on a mat and after cooling, it is mixed with yeast grown on rice and nosan leaves. The inoculated rice is poured into a cone-shaped bamboo basket and an earthenware pot is placed under the cone to collect the liquefied rice as it ferments. The juice is collected and transferred to new boiled rice about 3 or 4 times in succession. The total liquid collected becomes the first quality ruhi.

Microbiological and biochemical changes: The inoculum consists of molds belonging to genera Rhizopus and Mucor, as well as yeasts and lactic acid bacteria. Starch is hydrolyzed to sugar which, in turn, is fermented to ethanol. Final ethanol content ranges from 12 to 14% v/v. The pH of the ruhi is about 4.0. Reducing sugars are 2.5% w/v with total sugar being 3.0% w/v.

```
Boil raw rice
Drain and spread on mat
Inoculate with mixed organisms (from rice and nosan leaves)
Transfer to bamboo basket
Ferment 24 hr
Collect fermentation liquor as it is produced in earthenware
Pot (using funnel)
Inoculate into boiled, cooled rice Transfer to bamboo basket
Ferment 24 hr collecting fermentation liquor in earthenware pot
Inoculate into boiled, cooled rice
Transfer to bamboo basket
Ferment 24 hr
Collect fermentation liquor in earthenware pot
Ruhi (first quality)
```

Fig 12.3: Production of Indian Ruhi

12.7.3 Indian Rice Beer-Pachwai

The starter for Indian pachwai is bakhar. The bakhar contains Rhizopus sp., Mucor sp., and at least one species of yeast. Ginger and other plant materials are dried, ground, and added to rice flour. Water is added to make a thick paste and small round cakes of 1.0 to 1.5 cm in diameter and formed and inoculated with powdered cakes from previous batches. The cakes are then wrapped in leaves, allowed to ferment 3 days, and then sun-dried. Pachwai is manufactured by adding powdered bakhar to steamed rice and allowing the mixture to ferment 24 hr. The whole mass is then transferred to earthenware.
jars, water is added, and fermentation continues. The beer develops a characteristic alcoholic flavor and is ready to drink in 1 or 2 days.

**Check Your Progress 6**

**Note:**

a) Use the spaces given below for your answers.

b) Check your answers with those given at the end of the unit.

1. State the reasons to use rice for the production of alcoholic beverages.

2. What is the main ingredient in production of Indian ruhi and Indian madhu?

3. List the alcoholic beverages prepared from rice.

4. Differentiate microbiology and biochemical changes in Indian ruhi and Indian madhu.

5. Explain the process of making Indian beer.

---

**12.8 IDLI AND DOSA**

*Idli* is a small, white, acid-leavened, and steamed cake made by bacterial fermentation of a thick batter made from carefully washed rice and dehulled black gram dhal. The *idli* cakes are soft, moist, and spongy and have a desirable sour flavor. For *idli*, the rice is coarsely ground and the black gram is finely ground.

*Dosa* batter is very similar to *idli* batter, except that both the rice and black gram are finely ground. The batter also is thinner than that for *idli*. Following fermentation, the *dosa* is quickly fried as a thin, fairly crisp pan-cake and eaten directly.

*Idli* and *dosa* are produced primarily in South India and Sri Lanka, but they are known in other parts of India.

**Place in Diet and Quantity and Frequency of Consumption**

These foods are an important source of protein and calories in the diet and nutrition of South Indians. *Idli* or *dosa* constitute the breakfast of many South Indians, regardless
Idli and/or dosa are consumed for breakfast and often for supper in South India. In Sri Lanka, consumption is three or four times per week with the average person consuming two or three dosa at a meal.

**Outline of Idli Preparation (Figure 12.4)**

1. White polished rice is carefully washed and soaked for 5 to 10 hr.
2. Black gram; dhal is carefully washed and soaked for 5 to 10 hr.
3. The rice is then drained and coarsely ground in a stone mortar or other grinder.
4. The black gram is drained and finely ground in a stone mortar.
5. The rice and black gram slurries are combined to form a rather thick batter which is stirred with the hands.
6. Salt is added to taste. Other seasonings, such as chillies, are occasionally added.
7. The batter is placed in warm place to ferment overnight.
8. In the morning, the batter is poured into the cups of an idli steamer which is placed in a covered pan and steamed until the starch is gelatinized and the idli cakes are soft and spongy.

![Flow chart of Traditional Indian Idli production](image)

**Proportion of Water and Salt to Other Ingredients**

The amount of water added to the rice and dhal batter is varied from 1.5 to 2.2 times the dry weight of the ingredients. The batter should be made rather thick for idli and much more fluid for dosa. Generally a range of added water varies from 2.0 to 2.2 times the initial dry weights of rice and black-gram. It will thus provide the viscosity desired for...
dosa. Generally from 0.8 to 1% salt is added to the batter as a seasoning before fermentation.

**Fermentation Time**
Fermentation times vary from 14 to 24 hr, with overnight being the traditional time interval for idli-dosa. The fermentation time must be sufficient to allow a definite leavening of the batter and allow for development of pleasant acid flavor.

**Inoculum**
Ordinarily, the microorganisms developing during the initial soak and then during the overnight fermentation are sufficient to leaven idli.

**Incubation temperature**
Ordinarily, the idli-dosa fermentations are carried out at room temperature. In the tropics, optimum temperature of 25 to 35°C is recommended.

**Fermentation Containers**
The containers used for soaking the rice and black gram and subsequently for fermenting the batter should be of a sufficient capacity to hold the leavened batter and should be clean to avoid excessive contamination. It is customary to cover the fermentation container with a clean cloth to prevent the entry of insects.

**Harvesting and Preservation**
Idli and dosa are steamed as soon at the products have become leavened and acidified. They are generally consumed the same day and there is no effort to preserve the products. The acid content retards the growth of food poisoning and food spoilage organisms.

**Physical Changes Occurring in Batter during Fermentation**
The batter should rise approximately 50% above its original volume, but the batter may rise by as much as three times its original volume.

**Biochemical Changes Occurring in Substrate during the Fermentation**
In idli made with a 1:1 proportion of rice to black gram, batter volume increased about 47%, 12 to 15 hr after incubation at 30°C. The pH fell to 4.5 and total acidity rose to 2.8% (as lactic acid) in the same interval.

**Nutritive Changes**
Fermentation does little to improve the overall nutritive quality. Thiamin and riboflavin increase during fermentation and phyate phosphorous decreases. Fermentation results in an increase in both free and total niacin.

**Check Your Progress 7**

**Note:** a) Use the spaces given below for your answers.
        b) Check your answers with those given at the end of the unit.

1. What are the main differences in preparation of idli and dosa?

2. Describe outlines of idli preparation.
3. What are the operating parameters in *idli* making?

4. What are the physical and biochemical changes in substrate during fermentation?

---

12.11 LET US SUM UP

Broken rice is the by-product of the rice milling industry, varying between 30 and 50%. Brokens not only reduce the whole grain yield in milling process, but lead to economic loss due to its low selling price. After milling, it is necessary to separate broken kernels and germ from the whole grains for development of various value added products. The brokens mainly used for various types of flours (used for ready-to-eat breakfast cereals, crisped rice, infant cereals, French-fry coatings, powdered sugars, sauces, soups and gravies) and semolina, extraction of starch (used for cosmetic dusting powder, laundry stiffening agent, “custard” or pudding starch, baby foods and specific paper and photographic paper powder), canned rice, as brewing adjunct (wine and beer) and for preparation of breakfast foods, such as *idli, dosa* etc.

12.10 KEY WORDS

**Broken Rice**: Husked milled or hands produced rice consisting of broken grain or 3/4th of the whole grain but not less than 1/4th.

**Germ**: A coarse meal made from the sprout, or embryo, found inside the kernel.

**Brewer’s Rice**: Brewer’s rice refers to the small pieces of broken rice that remain after the milling process is complete. As the name implies, brewer’s rice is often used as ingredient for beer brewing.

**Brewing**: It is the art and process of making beer.

**Glutinous White Rice**: It is short-grained, very sticky and chewing rice.

**Gelatinization Temperature**: The temperature at which starch granules start to swell irreversibly in presence of hot water. It is evidenced by increased translucency and increased viscosity.

**Flour**: It is the powdery substance made from grinding grains.

**Indian Madhu**: It is a primitive, low alcohol rice wine produced and consumed in the Nagaland and Eastern hill region of India. It is salted to taste and is used as an early morning meal.

**Supernatant**: The soluble liquid reaction of a sample after centrifugation (or) precipitation of insoluble solids.
Semolina: The word derived from the Latin “simila” means fine white flour. It has a high protein content.

Waxy-rice: (also known as sweet or glutinous rice) is known for its exceptional stability and soft, creamy gel. It is a short and plump with a chalky white, opaque kernel.

12.11 SOME USEFUL REFERENCES


12.12 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Relatively cheaper by-product of rice milling industry, broken grains in milled rice varying between 30 and 50%, rice kernels are less than ¼ th of the size of the whole grain, it has low selling price. It is mostly used as feed, brewing adjunct and for preparation of breakfast foods.

2. Pre and post harvest operating conditions of paddy. Paddy variety has some effect on broken yield and type of milling machinery used also has effect on the broken yield.

3. Permissible limit of brokens generally vary between 18 and 25% of the total weight of the lot.

4. High capacity grading sifter, indented cylinder grader, colour and optical sorters.

5. Grading of rice kernels and the foreign objects on the basis of appearance or reflection of light to the specific sensor.

6. Rice kernels fall at a specific speed through camera, camera gathers light, photo-electrical sensor and trigger mechanism is activated, microprocessor electromagnetic valve operates with the compressed air blast line open.

Check Your Progress 2

1. Rice germ is embryo—the rudimentary form of future plant. It is very small. It is located ventral side of the caryopsis. Germs are almost 2 to 3% wt. of brown rice. Its protein efficiency ratio is around 2.59, while biological value is 78. The embryo contain 7.4% pentosans, 4% cellulose, 3 to 6% lignin, 11.6% reducing sugar, 2.1% non reducing sugar, 0.8% phytin phosphorous-4.6% free amino acids.
By-Products of Rice Milling

2. Laboratory-level separator, pneumatic separator and degermer.

3. Brown rice is fed into the perforated chamber, germ is removed due to friction caused between the grains. Germ recovery varies from 90 to 95%.

4. Mesh: 0.8mm φ, 1.5mm φ and 2mm φ

Check Your Progress 3

1. In wheat industry- milling produces flour, semolina etc.

   In rice milling industry- milling refers removal of bran for producing polished rice, and grinding brokens or polished rice produces rice flour.

2. Traditional Asian foods and baked goods, gluten free rice bread, baby foods, breakfast cereals and snack foods, unbaked biscuits, dusting powders and breading mixes, formulation of pan cakes and waffles.

3. Glutinous rice flour is used for oriented snack foods, thickening agent in whitesauces, gravies, puddings, frozen foods.

   Non glutinous rice flour is used to improve crispiness in crackers, as a thickener in soups and gravies, carrier for flavours and seasonings, and binding agent in meat products and rice pasta formulations.

4. Rice flour does not contain gluten. Its dough does not retain gases generated during baking.

   Wheat flour contains gluten. It provides elasticity in the dough to allow retention of CO2 gas generated during bread making process.

5. Ready-to-eat breakfast cereals, crisped rice for candies and snacks, infant cereals, French-fry coatings, extender in powdered cheeses and powdered sugars, waffle and pancake mixes and sauces, soups and gravies.

6. Rice flour chips absorb less fat during frying, less breakage.

7. Viscosity, starch gelatinization temperature, birefringence end point temperature, and water absorption capacity are the properties to measure the characteristics of rice flour.

8. Methods are wet, semidry, and dry milling.

   Main unit operations include soaking, milling, drying and regrinding.

9. Rice soaked in water for 4 hours, drained, and ground by a stone mill. Excess water is removed by drying and the flour is gently regrinding.

   Its uses are for making Japanese cake, rice crackers, Taiwanese cakes, rice noodles, Filipino rice cakes and Indian fermented foods such as idli, dosa etc.

10. Advantages cleaned rice can be ground to different sizes without generating waste water. The product so obtained has same protein content. Disadvantages more starch damage.

11. Baked products, baby foods, extrusion cooked products and in high protein flour.

12. Nutritional supplement in baby foods, instant milk, gruel, and puddings.


Check Your Progress 4

1. 0.3-0.5% sodium hydroxide

2. Steeping broken rice, wet milling, removal of cell walls, extraction of protein, washing and drying.
3. Starch damage is more in dry milling, resulting in great starch losses.

4. Steeping broken rice is done in 0.3-0.5% sodium hydroxide solution at room temperature to 50°C for 24 hrs.

5. Steeping milled or broken rice in 5-6 volumes of 0.2-0.3% sodium hydroxide steep liquor drain off, endosperms pressed and ground-slrurry diluted to original volume-mixture stirring and overnight settlement-cloudy supernatant drained off-sediment diluted to original volume-starch suspended in water and passed through mesh-starch collection by sedimentation or centrifugation.

6. Homogenizations of steeped grain in a waring blender and passing the resultant mixture through a mesh before sodium hydroxide treatment and continuous shaking for 3-6 h.

7. Lower alkali concentrations are ineffective for complete extraction of proteins and starch lipids.

8. 1-2% dodecyl benzene sulfonate.

9. 0.4% sodium hydroxide.

10. 5g of milled rice powder suspended in 45 ml of distilled water, subjected to stirring at 10 kHz for 10-20 min, homogenate filtration, scraping off dark upper layer, starch collection, washing and drying.

11. Size of starch granule varying from 3 to 10 μm, starch granules are compound, polyhedral or pentagonal dodecahedron, lower density, birefringence end-point.

12. Cosmetic dusting powder, laundry stiffening agent, “custard” or pudding starch, baby foods, specific paper and photographic paper powder.

Check Your Progress 5

1. High degree of grain stability throughout the canning process.

2. Soups and “dinners”, baby foods, plain and flavoured cooked rice, milky rice pudding.

3. Rice is precooked or blanched, washing, rice is put into cans, sealing is done under vacuum, retorted to sterilize the product.

4. The initial temperature is 40°C for 10-15 minutes. The recommended processing time at 118.3°C is 55 minutes. The sterilization temperature at 121°C is 13.29 minutes.

Check Your Progress 6

1. Rice contains low protein and lipid which favours the fermentation process.

2. Indian Madhu- raw rice
   Indian Ruhi- boiled rice

3. Sake in Japan, Shaoshin-chu in China, Madhu, Ruhi, Rice Beer in India.

4. Indian Madhu - Molds of genera Mucor and Rhizopus, final pH-3.8-4.5.
   Indian Ruhi- Molds of genera Mucor and Rhizopus, final pH-4.0, reducing sugars-2.5%, total sugar-3.0%.

5. Mixing of rice flour and ginger plant powder, addition of water, formation of small round cakes, inoculation, wrapped with leaves, fermentation, sun drying.
Check Your Progress 7

1. Idli- washed rice (coarse grinding) and dehulled black gram dhal (fine grounding)- white, acid leavened, and steamed cake

   Dosa- rice and black gram dhal are finely ground- fried as thin, fairly crisp pancake.

2. Polished rice and black gram dhal are washed and soaked in clean water. Washed rice and dehulled black gram dhal (fine grinding) are mixed along with water to make thick batter. Addition of salt and allow for fermentation, vary from 14 to 24 h, batter is poured in idli cups, then steaming, and the idli cakes.

3. 1.5 to 2.2 times dry weight of ingredients, fermentation time of 14 to 24 hrs, incubation temperature of 25 to 35 °C.

4. Batter should rise 50% above its volume, pH 4.5 and total acidity 2.8%.
UNIT 13 RICE BRAN

Structure
13.0 Objectives
13.1 Introduction
13.2 Composition and Properties of Rice Bran
13.3 Use of Rice Bran as Animal Feed and as Human Food
13.4 Processing of Bran for Protein
13.5 Extraction, Refining and use of Rice Bran Oil
13.6 Let Us Sum Up
13.7 Key Words
13.8 Some Useful References
13.9 Answers to Check Your Progress

13.0 OBJECTIVES
After reading this unit, you should be able to:
• understand importance of rice bran as a by-product of rice milling industry;
• explain composition and properties of rice bran;
• know about processing of rice bran for protein extraction;
• explain extraction, refining and use of rice bran oil for human consumption; and
• describe the importance of rice bran as animal feed and as human food.

13.1 INTRODUCTION
Bran is the hard outer layer of cereal grains, and consists of combined aleurone and pericarp. Along with germ, it is an integral part of whole grains, and is often produced as a by-product of milling in the production of refined grains. When bran is removed from grains, they lose a portion of their nutritional value. Bran is present in grains and may be milled from any cereal grain, including rice, wheat, maize, oats, and millet.

Bran is particularly rich in dietary fiber, and contains significant quantities of starch, protein, fat, vitamins, and dietary minerals.

Fig. 13.1: Longitudinal section of a paddy grain
Bran is often used to enrich breads (notably muffins) and breakfast cereals, especially for the benefit of those wishing to increase their intake of dietary fiber.

Rice bran (Fig. 13.2) finds particularly many uses in Japan, where it is known as *nuka*. Besides using it for pickling, Japanese people also add it to the water when boiling bamboo shoots, and use it for dish washing. In Kitakyushu City, it is called *Jinda* and used for stewing fish, such as sardine.

Rice bran is a by-product of the rice milling process, and it contains various antioxidants that impart beneficial effects on human health. It is well known that a major rice bran fraction contains 15%-20% oil and highly unsaponifiable components (4.3%). This fraction contains tocotrienol, gamma-oryzanol, and squalene. All these constituents may contribute to the lowering of the plasma levels of the various parameters of the lipid profile. Rice bran also contains a high level of dietary fibers (beta-glucan, pectin, and gum). In addition, it also contains 4-hydroxy-3-methoxycinnamic acid (ferulic acid), which may also be a component of the structure of non-lignified cell walls.

The high oil content of bran renders it to rancidification, one of the reasons that it is often separated from the grain before storage or further processing. The bran itself can be heat-treated to increase its storage life.

The amount of bran removed is called the degree of milling, that is, the percentage weight of brown rice removed. To get completely white and shining rice, it is necessary to remove 9% or more of the weight of the brown rice as bran (9% degree of milling). However, samples sold in the market generally contain much higher polish, at least of the order of 6-8%. We can therefore say in general that the amount of bran obtained in India is approximately 6-7 Kg. for every quintal of brown rice polished. Considering that paddy as purchased contains some impurities/driage, a quintal of paddy yields about 76 Kg. of brown rice. We can therefore say that the amount of bran obtained is approximately 4.5-5% of paddy, that is, about 5 Kg. bran for every quintal of paddy milled.

The yield of various products and by-products from paddy is summarised below:

<table>
<thead>
<tr>
<th>PADDY (100)</th>
<th>IMPURITIES (1-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HUSK (20-22)</td>
</tr>
<tr>
<td></td>
<td>MILLED RICE (average 70)</td>
</tr>
<tr>
<td></td>
<td>BRAN (3-8) (average 5)</td>
</tr>
<tr>
<td></td>
<td>HEAD RICE</td>
</tr>
<tr>
<td></td>
<td>BROKEN RICE</td>
</tr>
</tbody>
</table>
Husk, bran and broken rice are thus the three by-products of rice milling. For the health of any industry, utilization of its by-products is most important. Fortunately, all the three are valuable materials and have many uses. The properties and uses of bran are discussed here.

13.2 COMPOSITION AND PROPERTIES OF RICE BRAN

Types of Bran
The nature and composition of the bran obtained from rice depends on the system of milling and on any pretreatment given to the paddy. Accordingly, the following variables affect the bran:

- Huller versus disc sheller versus rubber roll sheller mills,
- Abrasion versus friction-type polishers,
- The stage of polishing,
- The degree of Milling,
- ‘Polish” versus bran,
- Whether germ is separated from the bran, and
- Bran from parboiled or raw rice.

When paddy is milled by single hullers (or by hand-pounding), a mixture of powdered husk and true bran is obtained. As a result, this bran contains very low amounts of oil and protein and high amounts of fibre (undigestable matter) and ash. It has very little industrial value.

When paddy is milled in sheller mills, it is first dehusked either in an under-runner disc sheller or in a rubber roll sheller and then polished in a polisher. A flow-sheet of the milling operation is shown below:

Flow sheet of the milling operation
By-Products of Rice Milling

A small amount of powdered material is obtained during dehusking (shelling) which is called ‘sheller bran’. The sheller bran from under-runner sheller is fair in amount and also contains some true bran and germ, in this system the dehusked brown rice has to pass over a large surface of emery and is thereby scratched to some extent. The amount of oil and protein in it is too small to be of industrial value. The sheller bran obtained after rubber-roll shelling contains very little true bran or germ and is mostly composed of powdered hulls and dust and has only fuel value.

The main rice bran of industrial importance is the true bran, that is, the outer layers of brown rice separated during its polishing. Here again two types of polishers are used, namely, the abrasion type (emery type) and friction type (metal type). In abrasion type polishers, the bran is cut out in small pieces from the grain surface by the sharp emery particles. As a result the bran also contains some endosperm (inner grain) matter. In friction type polishers, bran is removed in slightly larger pieces due to rubbing of the grains among themselves under pressure. So it contains less endosperm material and consequently a little more oil, protein and ash than bran from abrasive polishers.

Bran composition changes slightly with the stage of polishing. When the dehusked rice is polished in more than one polisher, oil, fibre and ash contents gradually decrease while starch gradually increases from the first to the last polisher. However, these differences are not important from the industrial standpoint and bran from different polishers are normally mixed together.

Presence or absence of germ in bran changes its composition slightly. The rice germ normally gets separated in stages during polishing of dehusked rice and gets mixed with bran. Rice bran as obtained from rice mills therefore includes rice germ (about 2% by weight). However, the germ is separated from bran by sieving and aspiration in the milling systems of some European countries (Spain, Italy). In this case the bran composition changed to some extent; especially the oil content is decreased.

Previous processing of rice, especially parboiling, changes bran composition and properties. This aspect is discussed in the next section. Heat treatment of bran for stabilization causes very little change in its composition and properties. But there is a partial agglomeration of bran and destruction of some enzymes.

In European and US mills, after removing the bran (whitening) in cone or horizontal polishers, rice is subjected to what is called ‘polishing’ operation in special equipments. In these ‘polishers’, rice is rubbed by leather straps instead of by emery. The idea is to remove all loose bran particles and a bit of the endosperm so as to give the rice a good shine. The material removed at this stage is called ‘polish’. In composition, ‘polish’ is intermediate between bran and endosperm. Oil, protein, fibre, ash and vitamins in ‘polish’ are less than in bran but more than in endosperm. It should be noted that in India such ‘polishers’ are not used, and whitening itself is generally called polishing. So the terms ‘polishers’ and ‘polishing’ as used in India should not be mixed up with the same terms used in European and US writings.

Composition of Rice Bran

The range of compositions of rice bran (excluding huller mill bran and ‘sheller bran’) is shown in Table 13.1. These data relate to bran from raw rice. If rice is parboiled, the aleurone layers of the grain are broken up by parboiling and the oil is pushed outward. Therefore more of the oil comes into bran during milling. On the other hand, some of the vitamins and minerals in the outer layers are retained in the milled rice after parboiling, so that bran from parboiled rice contains less vitamins and minerals.

Carbohydrates (nitrogen-free extract) constitute some 30-50% of bran. They consist of varying amounts of starch (depending on how much of endosperm is polished), free sugars, cellulose and hemicellulose. Bran also contains some lignin. Cellulose, hemicellulose and lignin are parts of ‘fibre’ and are indigestable.
On an average rice bran contains about 15% protein. Non-protein nitrogen accounts for about 16% of total nitrogen; most of it is in the form of free amino acids. Proteins are of many kinds, depending on, in what medium they can be dissolved, namely:

- albumin - soluble in water,
- globulin - soluble in salt solution,
- prolamin - soluble in alcohol, and
- glutelin - not soluble in anything.

Rice protein consists mostly of insoluble glutelin (about 80%) and of only small amounts of albumin.

Globulin predominate in the outer layers of brown rice. As a result, protein composition in the bran is quite different from that in milled rice and consists mainly of albumin, globulin and small amounts of prolamin and glutelin. The comparative compositions of bran, rice and germ proteins are shown in the figure below. As albumin and globulin contain more lysine than glutelin, the lysine content of rice bran is more than that of whole rice grain (Lysine is an amino acid. Several amino acids join together to form a protein. Some 20 amino acids are found. Lysine is low in rice and in all other cereal proteins).

### Table 13.1: Chemical composition of rice bran and germ

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Unit</th>
<th>Range of values in Bran</th>
<th>Germ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>%</td>
<td>12 - 17</td>
<td>15 - 25</td>
</tr>
<tr>
<td>Fat (oil)</td>
<td>%</td>
<td>13 - 23</td>
<td>17 - 40</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>%</td>
<td>34 - 54</td>
<td>35 - 42</td>
</tr>
<tr>
<td>Starch</td>
<td>%</td>
<td>10 - 25</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Free sugars</td>
<td>%</td>
<td>3 - 7</td>
<td>8 - 12</td>
</tr>
<tr>
<td>Pentosans</td>
<td>%</td>
<td>5 - 8</td>
<td>5 - 7</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>%</td>
<td>9 - 17</td>
<td>9 - 15</td>
</tr>
<tr>
<td>Cellulose</td>
<td>%</td>
<td>5 - 10</td>
<td>3 - 7</td>
</tr>
<tr>
<td>Lignin</td>
<td>%</td>
<td>3 - 10</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Crude Fibre</td>
<td>%</td>
<td>6 - 14</td>
<td>2 - 10</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>7 - 15</td>
<td>5 - 11</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>1 - 3</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Potassium</td>
<td>%</td>
<td>1 - 2.5</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.5 - 1.3</td>
<td>0.4 - 1.5</td>
</tr>
<tr>
<td>Silica</td>
<td>%</td>
<td>0.5 - 1.5</td>
<td>-</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/100 gm</td>
<td>30 - 130</td>
<td>20 - 100</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/100 gm</td>
<td>9 - 50</td>
<td>10 - 50</td>
</tr>
<tr>
<td>B1 (Thiamine)</td>
<td>mg/100 gm</td>
<td>1.2 - 3.0</td>
<td>4 - 8</td>
</tr>
<tr>
<td>B2 (Riboflavin)</td>
<td>mg/100 gm</td>
<td>0.2 - 0.4</td>
<td>0.2 - 0.5</td>
</tr>
<tr>
<td>Nicotinic acid</td>
<td>mg/100 gm</td>
<td>25 - 50</td>
<td>2 - 10</td>
</tr>
<tr>
<td>E (Tocopherol)</td>
<td>mg/100 gm</td>
<td>2.5 - 13</td>
<td>8 - 10</td>
</tr>
</tbody>
</table>

There is a large variation in the gross chemical composition of Rice Bran (Table 13.2)
Table 13.2: Variation of gross chemical composition of rice bran

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Minimum (%) dry basis</th>
<th>Maximum (%) dry basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>11.5</td>
<td>17.2</td>
</tr>
<tr>
<td>Fat</td>
<td>12.8</td>
<td>22.6</td>
</tr>
<tr>
<td>Fibre'</td>
<td>6.2</td>
<td>14.4</td>
</tr>
<tr>
<td>Ash</td>
<td>8.0</td>
<td>17.7</td>
</tr>
<tr>
<td>Nitrogen Free Extract (NFE)</td>
<td>33.5</td>
<td>53.5</td>
</tr>
</tbody>
</table>

As the rice grain is a living seed, it contains many enzyme systems located mostly in the germ and aleurone layer (enzymes are what make chemical reactions go on in a living cell). Most of these enzymes come into the bran after milling. Hence, rice bran is rich in various enzymes. While other enzymes are not of much industrial importance, the presence of lipase in bran is of great importance, as will be discussed later. Most rice enzymes are destroyed during parboiling, hence bran from parboiled rice contains little or no enzymes.

Rice bran contains relatively large amounts of minerals as can be seen from its high ash content (Table 13.2). Among the minerals, the predominant component is phosphorus. It amounts up to 3% in bran. The other important minerals are potassium, magnesium and silicon. Calcium and iron, two important nutrients, are rather low. The content of minerals in bran increases first as rice is polished and then decreases with further polish. About 90% of the phosphorus is present in the form of phytin. This is important from the standpoint of nutrition, for phytin is rather harmful as will be discussed later.

Rice bran contains high levels of B vitamins (see Table 13.2). This is because most of the vitamins in raw rice is located in the outer layers, which are therefore removed into the bran during milling.

As explained earlier, much of the vitamins and minerals are retained in the milled grain after parboiling and accordingly bran from parboiled rice contains much less vitamins and minerals.

How does rice bran compare with brans from other cereals? Other brans generally do not contain germ, while rice bran usually includes the germ. This is one reason why the fat (oil) content of rice bran is much more than bran from other sources. Protein and fibre content of rice bran are similar to those of other brans. But rice bran is richer in ash, especially silica, and also in phosphorus, 90% of which is in the form of phytin which is the highest among all cereal brans.

The amino acid composition of rice bran is by far better than those of other brans. Bran protein is richer in lysine than that of whole rice, for it contains more of albumin and globulin (which contain more lysine than glutelin) than in the total grain. For this reason, the nutritive value of rice bran protein is more than that of other bran proteins. However, lysine and threonine are still the limiting amino acids in rice bran as in other bran proteins.

Properties of Rice Bran

The particle size distribution of bran varies depending on its source. Friction type polishers produce bran of larger particle size than abrasion type polishers. In polishing cones the percentage of fine particles tends to increase with successive cones. Heat stabilization tends to bring about agglomeration of rice bran particles. Bran from parboiled rice is flakier with larger particle size than bran from raw rice. The germ in rice bran is generally bigger in size than its other components.

The bulk density (weight per volume of bran in bulk) of rice bran is very low (Table 13.3). But the true density (weight per volume of each bran particle) is close to that of milled
rice. Its angle of repose (angle formed by a heap) is about the same as that of rice and paddy. Its equilibrium moisture content (moisture content attained when exposed to air) is about 2% less than that of milled rice. The highest safe moisture content for its storage is 10-12%.

<table>
<thead>
<tr>
<th>Property</th>
<th>Bran</th>
<th>Germ</th>
<th>Milled Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density (gm/cc)</td>
<td>0.2 - 0.4</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>True density (gm/cc)</td>
<td>1.2 - 1.3</td>
<td>-</td>
<td>1.45</td>
</tr>
<tr>
<td>Angle of repose (degree)</td>
<td>38</td>
<td>-</td>
<td>38</td>
</tr>
<tr>
<td>Equilibrium moisture at 75% RH (% wet basis)</td>
<td>12</td>
<td>-</td>
<td>14</td>
</tr>
</tbody>
</table>

**13.3 USE OF RICE BRAN AS ANIMAL FEED AND AS HUMAN FOOD**

It is evident that bran is a very valuable product for many applications as illustrated in Fig.13.3

Nutritional Value of Rice Bran

The protein content of bran is around 15%, which clearly puts rice bran as an important source of protein. The protein goes up further in deoiled bran (17-20%). The amino acid composition of rice bran protein compares favourably with those of other cereal brans, oilseeds and even cereal grains including wheat and maize. The chemical score of the protein as per the FAO/WHO reference pattern is 80% for first limiting amino acid level (lysine) and 90% for the second limiting amino acid level (threonine). Another method of measuring the nutritive value of a protein is by feeding it to young rats and measuring the 'protein efficiency ratio' (PER), that is, the gain in rat’s weight in gram per gram of protein eaten. The PER of rice bran protein is around 1.8-1.9; that of germ protein is slightly higher (2.0). These values compare favourably with those of grains like wheat (1.0), maize (1.2), groundnut (1.7) and rice (1.9); cow’s milk has a PER of 2.5 and egg 3.8. However, the digestibility of the protein (in the rat) is not very good. This is caused by the high amounts of fibre and phytin in bran and by the fact that most of the protein is in the form of protein bodies.
Digestibility of bran organic matter (protein, lipids and carbohydrates) is good, in sheep, although low in the case of fibre. Defatting improves digestibility. Hence, the final nutritional value as well as the calorific value of the defatted bran is nearly the same as that of original full-fat bran (for sheep). Presence of husk in bran reduces digestibility. Digestibility of hulls for non-ruminants is practically zero, although some hulls are customarily fed to poultry. The amount of total digestible nutrients in bran is higher than that in wheat bran and is quite comparable to wheat endosperm and oats.

It is needless to say that full-fat bran is a good source of calories as well as essential fatty acids as it contains so much oil.

Rice bran is an excellent source of B vitamins and vitamin E. Contents of these vitamins are reduced in bran from parboiled rice because the vitamins are partly retained in the milled rice when parboiled.

The minerals in bran and their role in nutrition are discussed below.

13.4 PROCESSING OF BRAN FOR PROTEIN

Since the protein content of rice bran is higher than any other portion of the rice kernel, full-fat, stabilized full-fat or defatted bran can be effectively utilized for production of high-protein flour or protein concentrate which can be used as food-grade material. Technology of processes from production of these materials to be used in bread and other bakery products in admixture with wheat flour is being developed in some countries. Some of the processes have come up to the pilot plant stage also.

Utilization of full-fat bran for edible purpose is, however, limited by two major drawbacks: instability and high fibre content. Satisfactory bran stabilization methods are available but fibre still remains as the major problem, because it affects (a) palatability, (b) availability of nutrients and (c) the functional properties of the whole product.

Fractionation of bran can isolate the protein and thereby solve the problem by decreasing the fibre.

The process of fractionation may be divided into two categories: (1) Dry methods based on segregating portions of the bran by grinding, sieving or air-classification, and (2) Wet methods based mostly on the solubility of rice bran protein in water or in alkaline medium. High-quality protein concentrates can be prepared by this method.

Dry method – The first attempt on grinding and sieving at 40-mesh yielded about 30 per cent as refined bran, which contained 14 per cent crude fibre and could be used as feed for non-ruminant. Another product was obtained by sieving through a 100-mesh screen and contained 12 per cent protein and only 5 per cent crude fibre. It could be used as food ingredient.

A three-stage process consists of screening in a 20-mesh sieve, grinding the fines in a flour mill and screening through 75-mesh sieve and final screening through a set of sieves (80, 100, 140 and 200 mesh). The product – 140 mesh is ¼ the original bran and contains 15-16 percent ash and 1-1.5 per cent fat.

Wet methods – Water extraction method consists of soaking rice bran in water under controlled conditions, grinding the soaked bran and screening to remove the fibres. The particle-size of bran is the key factor in separation of the components. Grinding in disc, rotary or colloid meals have been found to be effective. Screens, hydroclones or a combination of these are employed to remove the fibres. The fractions are dewatered by centrifuge and dried. A latest fractionation process yielded three fractions:

(a) a high-protein low fibre flour, approximately 60 per cent by weight,
(b) a high-fibre protein meal, 30 per cent by weight and
(c) a fraction rich in sugars, vitamins and minerals, 10 per cent by weight.
Results showed that the low-fibre fraction has the high food potential and the high-fibre has a good food-value.

Alkali extraction method – Defatted bran is extracted with aqueous alkali at room temperature at pH 11 followed by precipitation of solids by reducing pH to 5.5 with hydrochloric acid, centrifuging and drying. A 94-99 per cent protein concentrate, which is 30 - 40 per cent of the original total protein. A pilot plant two-stage alkaline extraction sieved a 75 per cent concentrate whose limiting lysine content was 4.11 per cent based on the total protein.

**Anti-Nutritional Factors in Bran**

Rice bran contains some anti-nutritional factors, although most of these are only of minor significance.

Phytin is the most important factor 90% of bran phosphorus exists in the form of phytin. It is located in the protein bodies of the aleurone. The phosphate groups of phytin get complexed with calcium, iron and zinc, which are already low, and also with protein, and tend to render them unavailable for nutrition. Rice bran contains the highest amount of phytin among all cereal brans. When incorporated as fibre at 6% level in chick diet, only rice bran among various brans reduces growth and bone deposition.

Calcium/phosphorus and phytin/zinc ratios are important in nutrition. A ratio of 1.2 to 2 of the former is desirable but it is less than 0.1 in rice bran (but the ratio is equally low in other grain brans as well). Phytin/zinc molar ratio of over 10-15 depresses growth in rats. But this molar ratio is around 30-40 in rice bran (also in other grain brans). On the other hand, increasing the calcium content in bran by adding calcium carbonate (for example to help in polishing of brown rice) depresses bioavailability of zinc.

Trypsin inhibitor is a toxic factor present in rice bran in small quantities. It is easily inactivated by steaming, although not by dry heat. It is an albumin and is present mostly in the germ.

Hemagglutinin is another toxic factor and is a globulin. A similar factor is lectin which is a glycoprotein. All these are easily destroyed by heat.

Dietary fibre, which is high in bran, can also act as an anti-nutritional factor in excessive amounts. The amount of dietary fibre as determined by enzymatic and biological methods is about four times that of the chemically determined crude fibre. Excessive fibre decreases digestibility of nitrogen and also binds some minerals like calcium and iron. Highly pigmented rice varieties contain some tannins in the bran layer, which also binds nutrients.

**Use of Rice Bran for Human Food**

Use of rice bran as a possible food ingredient has been long thought of. Dr. Salvadore Barder of Spain in a review article in 1974 wrote “everything would indicate that the possibility of using rice bran as food is imminent”. This possibility is being realized now.

It has been reported that the carbohydrate fraction of rice bran contains nutritionally important dietary fibre which has hypo cholesteremic, hypoglycemic and laxative properties. In fact, these properties of rice bran are next only to that of oat bran among all cereal brans. Food uses of rice bran have been explored in other countries in which both full fat and deoiled bran form has been used in baby foods, breads, muffins, pancakes, cookies, cakes, pies, coatings and crusts for finger foods, confectionery, spice carriers, deep fried preparations, extruded snacks and breakfast cereal. Recently processed bran have also appeared in western markets for use as additive and source of dietary fibre in various foods at home.

The Rice Millers Association of USA adopted a definition and minimum standard for full-fat stabilized raw and parboiled rice bran for food uses.

Protein concentrates obtained from bran as described below have the potential of being possibly used in various products. Milk-like or beverage-like products have been made from bran either by water extraction of full-fat bran or from the concentrates mentioned.
By-Products of Rice Milling

The functional properties of rice bran proteins should be of major importance in possible use of bran proteins in food formulations. But such functional properties of bran proteins (solubility, water absorption, emulsification, fat absorption, viscoelasticity, foaming) have not been extensively studied yet.

Edible Fractions from Bran

The utilization of bran for food is limited by two main factors: its instability and its high fibre content. The instability aspect has been now largely solved by development of stabilization processes. Attempts have been made to reduce the fibre content as well as to increase the concentration of other nutrients by various fractionation procedures.

Attempts at dry fractionation of rice bran either by sieving or by air classification with or without further grinding with the aim to obtain a nutrient-rich fraction but with less fibre has not been very successful.

Some success has been achieved with wet fractionation systems. Both alkaline extraction and water extraction have been tried.

Solubility of bran proteins increases with increasing pH (that is, alkaline). This is the basis of two or three systems in which rice bran is extracted with dilute alkali at a pH ranging from 9-11.5. The solution is separated by centrifugation. The protein is then precipitated with acid at the isoelectric pH of about 4-4.5. Some more protein can be recovered from the solution by coagulating with heat. The material is dried in a drum dryer. Protein concentrates having up to 85% protein can be obtained in this way, recovering up to 50% of the bran protein. The concentrate has essentially the same amino acid composition as in the original bran and good PER value.

In an alternative approach, rice bran suitably ground in dry or wet state is extracted with water. The slurry is either decanted or screened to remove the fibre. Suitable treatments of heating, centrifugation and screening can give three fractions: a high-fibre (18%) intermediate-protein (13%) residue, a low-fibre (less than 3%) higher-protein fraction (16-20% protein), and a syrup containing the water soluble vitamins and other nutrients. The second fraction can be used in food and the first in feed.

While these attempts have shown the potential of obtaining high value fractions from rice bran, their use in food remains to be achieved.

Use of Rice Bran as Animal Feed

Use of rice bran in composite feeds has the following limitations: (1) high amounts of fibre, (2) high amounts of unsaturated fat, (3) presence of calcium and phosphorus in undesirable proportions, (4) high amounts of phytin, (5) sometimes too much sand and silica, (6) variable composition, and (7) high instability.

The dry matter of ration for an animal with a single stomach (non-ruminants) should not contain more than 6% fibre, but the fibre content of ruminants may be as high as 35%. For this reason bran cannot be used in unlimited quantities in single-stomach animals.

The high unsaturated oil content of bran prevents its use in unlimited proportion in animal rations. The body fat, for instance in pigs, is thereby affected and becomes too soft. But deoiled bran, naturally, does not cause this problem.

The problem caused by the calcium/phosphorus ratio and phytin have already been discussed. Similarly the amount of sand and silica in compound feeds should not be more than 4%, but rice bran that has been made or handled improperly often has more.

In industrial manufacture of balanced feed, too much variation in the composition of a raw material, as is common in rice bran, is quite undesirable.

Chemical instability of bran is another factor. Fat hydrolysis develops FFA (free fatty acids), while oxidation may lead to undesirable compounds as well as bitter taste. Deoiling of bran leads to greater stability. Heat stabilization prevents FFA development and also
helps in reducing the activity of micro-organisms and other pathogenic and/or toxic factors in rice bran.

Rice bran is used satisfactorily in pig diets, up to 20-40% in the ration. Upto 40-50% bran can be used in the diet of poultry. However use of unstabilized bran in poultry feed is risky, for unsaturated acids in the process of becoming rancid may lead to loss of tocopherols and hence to vitamin E deficiency. Upto 60% bran can be used in the ratio of dairy cows.

13.5 EXTRACTION, REFINING AND USE OF RICE BRAN OIL

Pressing

As the oil content of rice bran is rather low, oil cannot be easily prepared from bran by pressing. However, pressing was a common practice in Japan in olden times (before World War II) and has also been practiced in China, Vietnam and Thailand. The process in Japan involved steam cooking of bran at a pressure of 4-5 kg/cm² and then drying. Bran was then prepressed at a pressure of 70 kg/cm² followed by ring or cage hydraulic pressing at a very high pressure (100-1000 kg/cm²). Continuous expellers at still higher pressures were also used. A little over half the bran oil can be pressed out by these methods. One advantage is that the crude oil is of purer quality than that obtained by solvent extraction.

This method of bran oil preparation has been now totally given up in Japan and is planned to be gradually replaced by some new process in China and Vietnam.

Solvent Extraction

Solvent extraction has the advantage that it can recover almost the entire amount of oil in the bran (residual oil in bran, 1-1.5%). But it has the disadvantage of extracting many impurities and colour so that refining of the oil is more expensive. The methods largely follow the conventional extraction and refining technologies. However, one should note that the oil content of bran is not very high, 12-25%, and the material is powdery. Also the oil contains certain special compounds. Hence, some modifications of the standard technology are adopted.

Extraction can be of batch, battery or continuous type. The batch and battery systems are generally used in Japan. Continuous extraction plants have larger capacity and are being operated in many places (India, Burma, Egypt, Mexico, Taiwan and Thailand).

Batch extraction is the oldest system. The pretreated bran is placed in one or more extractors, Hexane is pumped in and the solvent level is maintained to percolate the bran and extract the oil. The miscella (mixture of oil and solvent) is passed through a filter to an evaporator for desolventizing.

In battery extraction, several extractors are arranged in series, and miscella obtained from one is passed through the other extractors one after the other in a counter-current system. Fresh solvent is applied only to the last extractors. This is a semi-continuous system.

Continuous extraction achieves the highest economy in steam, power, labour and material but is more sophisticated and is suitable only when the capacity is at least 50 tonnes per day. It uses the counter-current principle and is either of immersion or percolation type. A filtration-extraction process is also used. The plants commonly used include De Smet type from Belgium, rotating O-W type from Japan, Lurgi type from Germany and Rosedown type from England.

While in the batch or battery system bran as such can generally be used, its pelletization is essential in the continuous system. This is necessary to reduce the problem of channeling in extraction and of fines which clog the filters as well as pass through the filters to make
By-Products of Rice Milling

The oil turbid. To prevent this, bran is made into pellets of 6-8 mm size. Stabilization by moist heating causes agglomeration of bran in which case pelletization may not be required. Stabilization of bran by extrusion cooking produces flakes, in which case pelletization is unnecessary. In batch plants, where pelletization is not essential, some processors add coarse husk to help extraction; the husk is later on removed from the dry deoiled bran by sieving.

Although hexane is the solvent of choice and has been universally applied in solvent extraction, other solvents may have some special advantages. Ethyl or isopropyl alcohol have been tried. These have the advantage of extracting less wax, which means dewaxing problem is eliminated, and of extracting sugars and B vitamins which can be recovered as a by-product syrup. However, alcohol extracts more colour, causing difficulty in bleaching, and reduces the nutritive value of the extracted bran by dissolving the B vitamins.

Parboiled bran contains more oil and should therefore be a preferred material for extraction. However, processors have sometimes reported problems with it. First, parboiled bran is more difficult to pelletize and may require some special conditions. To overcome this problem, some processors mix raw bran with parboiled bran, which however causes FFA (free fatty acids) problem. Second, predrying of parboiled bran is essential for batch extraction. Third, parboiled bran needs a longer time and more number of extractions to extract all its oil. In batch extractors parboiled bran needs at least three solvent washings to recover all oil. Finally, improper parboiling may darken the oil colour.

Refining of Rice Bran Oil

In India, rice bran oil has only recently begun to be used as cooking oil. As far as food use is concerned, so far it has been used only for making Vanaspati, for which purpose oil with less than 8-10% FFA is considered acceptable and this oil is called "edible rice bran oil" in the trade. Genuine edible-grade oil to be used for cooking/salad oil requires refining.

Other vegetable oils are generally prepared in India by pressing and can be directly used in food. But rice bran oil is prepared by solvent extraction and as such it has to be refined for use in cooking. Refining is also necessary in view of the presence of acids in it. Even if the oil is prepared from fresh or stabilized bran, the amount of FFA in the oil is usually more than 3%, making it generally unsuitable for direct use in food.

Refining of rice bran oil is more difficult than other vegetable oils due to three reasons: (1) Alkali refining of bran oil causes much higher loss of oil than in other oils due to reasons not fully understood. (2) Rice oil, unlike other oils contains wax, removal of which is a little complicated. (3) Heat treatment, including improper parboiling and improper heat stabilization, and especially in presence of high FFA, causes darkening and fixation of colour in the oil, which is difficult to remove by bleaching.

For use in Vanaspathi, the pooled low-FFA bran oil is first deacidified, bleached and deodorized; the wax is not removed, for it gets diluted by being mixed with other oils. But it should be noted that even for refining, the FFA in the oil should not be too high, otherwise the refining losses become excessive. Moreover, oil with too high FFA cannot generally be made edible even by refining, because the proportion of glycerides in the oil may have changed unfavourably.

Refining of crude rice bran oil involves the following steps:

- **dewaxing** - to remove wax,
- **degumming** - to remove phosphatides,
- **neutralization or deacidification** - to remove FFA (free fatty acids),
- **bleaching** - to remove colour,
- **deodorization** - to remove smell,
- **winterization** - remove saturated glycerides.
Rice bran oil is unique in possessing a fairly high amount of wax. The wax causes much difficulty in subsequent refining and therefore must be removed before other steps of refining are attempted. The wax is soluble in oil-hexane miscella at usual extraction temperatures (60-70 °C) but is virtually insoluble at low temperatures. A double extraction system is therefore one approach to dewaxing, although this is expensive. The bran is first extracted with hexane at a low temperature (4-5 °C), when the wax remains insoluble, giving a wax-free oil. The bran is then extracted a second time at 60 °C, which on cooling yields wax as a precipitate. Alternatively, the conventional hot-solvent extraction followed by cooling of the miscella or of the desolventized oil can separate wax by deposition. The separated wax can be collected by centrifugation or filtration or by slow settling. However, as the viscosity (thickness) of the oil increases on cooling, separation of wax from oil by cooling is time consuming and hence expensive in tropical countries. Dewaxing in miscella (mixed with hexane) is easier as the viscosity is thereby reduced. But the process involves additional cost. Recently it has been observed that separation from the oil can be more easily achieved by adding a solution of a surface-active agent which wets the wax particles and helps their merging and separation.

Degumming

Gums and mucilages in vegetable oils generally consist of phosphatides and glycolipids. They may also include sugar and protein complexes in colloidal form. Prior degumming of oil is important, for polar lipids have surface-active properties and form an emulsion with the soap-stock formed during deacidification. So the soap-stock does not easily separate and occludes a lot of oil, thus leading to high losses of oil during neutralization. Phosphatides, if recovered, are valuable by-products, like lecithin. In case of deacidification by distillation or during heating for other reasons, prior degumming is a must, for otherwise high discoloration occurs during heating which is very difficult to bleach. Degumming is normally carried out by adding small quantities of phosphoric or citric acids followed by filtration or settling. Alternatively steam can be passed into the oil up to a temperature of 80-100 °C, or the oil can be heated with addition of a little water, which separates gum by flocculation (mutual adhesion and floating).

Deacidification

Removal of FFA from rice bran oil generally causes much problem. Due to some unknown reasons, high losses of oil occur during its alkali neutralization. However, prior dewaxing and degumming followed by carefully controlled addition of caustic soda and controlled time and temperature of heating can reduce refining losses to a minimum. One reason of the high loss of neutral oil during alkali refining is the fluffy and thin nature of the soap-stock which is difficult to separate and which therefore occludes considerable amounts of oil. Effort to reduce refining losses is directed to harden the soap-stock so that it settles easily without including any oil. Addition of certain chemicals such as sodium silicate, sugars (molasses), ethanolamine and some alcohols and glycols seem to achieve this and reduces refining loss.

Miscella refining (mixed with hexane) is an effective method of reducing refining loss, for the soap-stock separates easily in this case. Refining in the miscella has the additional advantage of giving less coloured oil.

Soap is obtained as a by-product of alkali neutralization. As the oil is mostly unsaturated, the soap is soluble in cold water.

Miscella refining using binary solvents (hexane and alcohol) is also done. The soap dissolves in the alcohol layer. Refining loss is low, but the process is expensive. Soap is recovered from the alcohol layer as fatty acids.

Another method of deacidification is to remove FFA by steam distillation in which case the free fatty acids are obtained as valuable by-products. The oil is heated to 200-240 °C.
under a high vacuum of 3-4 millimeters of mercury and is subjected to steam stripping. The free fatty acids distil over and are collected as distillate. There is no refining loss. However, the process is somewhat expensive. Its another disadvantage is that the oil colour tends to get deepened and fixed, leading to bleaching difficulty.

It has been suggested that high-FFA oil can be converted to low-FFA oil by any of the physical refining systems (distillation, miscella refining), and the low-FFA oil can then be further refined by alkali treatment or used in Vanaspati.

**Bleaching**

Bleaching of rice bran oil is carried out by conventional use of bleaching earths and activated carbon. Most pigments can be readily absorbed by bleaching earth or destroyed by heat, but oxidation, particularly in the presence of traces of iron or copper, can lead to fixing of colour and resistance to bleaching. Heating in presence of gums can also lead to darkening and difficulties in bleaching.

**Deodorisation**

This is carried out by heating the oil to 200 °C - 250 °C under high vacuum with dry steam to remove all volatile materials giving smell.

**Winterization**

If the oil is to be stored at refrigerated temperatures, such as for salad oil, winterization is necessary. The purpose of this step is to remove saturated glycerides which cause cloudiness to the oil when stored in cold. Winterization is achieved by chilling the oil and allowing the saturated fats to settle out.

**Use of Rice Bran Oil**

The characteristics of rice bran oil are broadly similar to other vegetable oils. Its fatty acid composition is roughly as follows:

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oleic acid</td>
<td>40-50%</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>30-35%</td>
</tr>
<tr>
<td>Palmitic acid</td>
<td>15-20%</td>
</tr>
<tr>
<td>Others</td>
<td>5-10%</td>
</tr>
</tbody>
</table>

**Table 13.4: Valuable materials present in or obtained from rice bran oil**

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount (% in oil)</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wax</td>
<td>2-6</td>
<td>In polish, food wraps, cosmetics, leather, etc.</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>0.1</td>
<td>Medicinal, as antioxidant</td>
</tr>
<tr>
<td>Squalene</td>
<td>0.3 – 0.4</td>
<td>Medicinal</td>
</tr>
<tr>
<td>Oryzanol</td>
<td>1 - 2</td>
<td>Medicinal, as antioxidant</td>
</tr>
<tr>
<td>Fatty acids</td>
<td>Variable</td>
<td>Industrial</td>
</tr>
<tr>
<td>Soap</td>
<td>Variable</td>
<td>Industrial</td>
</tr>
<tr>
<td>Gums (Phosphatides)</td>
<td>1 - 3</td>
<td>Like Lecithin. Emulsifying, wetting, dispersing</td>
</tr>
<tr>
<td>B Vitamins</td>
<td>In bran</td>
<td>Medicinal</td>
</tr>
<tr>
<td>Phytin</td>
<td>In bran</td>
<td>Food Processing industry</td>
</tr>
<tr>
<td>Inositol</td>
<td>From phytin</td>
<td>Medicinal</td>
</tr>
<tr>
<td>Microchemicals</td>
<td>In bran</td>
<td>Industrial and medicinal</td>
</tr>
</tbody>
</table>
High FFA rice bran oil can only be used for industrial purposes, including for making soap. As the oil is soft (it contains predominantly unsaturated fatty acids, as shown in Table 13.4), it is often hardened by hydrogenation before being put to industrial use.

Refined rice bran oil is good cooking oil. If properly winterized, it can be used as salad oil. It has low linoleic acid and high tocopherol contents, thus rendering it more resistant to oxidation than many other vegetable oils. At the same time its high amounts of oleic and linoleic acids make it a rich source of essential fatty acids and highly nutritious. It has a good cholesterol-lowering effect. Rice bran oil with less than 8-10% FFA is routinely used in making Vanaspati in India.

Crude as well as refined rice bran oil have many other industrial uses in small quantities.

By-Products of Refining

Rice bran oil contains many important materials which are obtained during its refining (Fig. 13.4). The wax is of high melting point (75-80°C) which is not found in other vegetable oils. It is very similar to carnauba wax and has many industrial and cosmetic uses. Vitamin E (tocopherols) and squalene have medicinal properties. Oryzanol is an ester of ferulic acid and triterpenoid alcohols and is reported to have valuable pharmaceutical properties.

The above and many other chemicals and pharmaceuticals, including B vitamins and phytin, can be prepared from rice bran or the oil.

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**Check Your Progress**

**Note:** a) Use the spaces given below for your answers.
   b) Check your answers with those given at the end of the unit.

1. What is rice bran and what does it contain?

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---
2. What is the quantity of bran obtained from milling one quintal of paddy?

3. What affects the bran composition?

4. What type of protein is contained in rice?

5. What is the true density of rice bran and its angle of repose?

6. What are the different uses of rice bran?

7. What are different stages of refining of crude rice bran oil?

13.6 LET US SUM UP

Rice bran is the most important by-product of rice milling (paddy processing) industry all over the world. The term bran is applied to the outer layers of the grain removed from brown rice during milling. It consists of pericarp and seed coat together with a major portion of the aluerone layer, part of the endosperm and the germ.

Rice bran contains about 15-20% oil by weight of bran which is extracted by pressing or solvent extraction process. This oil is called crude oil. This oil when subjected to the process of refining consisting of dewaxing, degumming, neutralization or deacidification, bleaching, deodorization and winterization yields oil fit for human consumption and is rich in micronutrients and B-group vitamins etc.

Defatted bran devoid of oil is an important source of animal and poultry feed. Efforts are in process to utilize it as human food.
### 13.7 KEY WORDS

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Bran</td>
<td>A hard outer layer of unpolished (brown) rice grain</td>
</tr>
<tr>
<td>By-product</td>
<td>A product obtained out of the main process (like bran in rice milling).</td>
</tr>
<tr>
<td>Degree of milling</td>
<td>It is the percentage weight of brown rice removed to get white rice</td>
</tr>
<tr>
<td>Rice husk</td>
<td>A outer layer covering the paddy grain which consists mostly of silica.</td>
</tr>
<tr>
<td>Albumin</td>
<td>A protein in rice bran which is soluble in water</td>
</tr>
<tr>
<td>Glutelin</td>
<td>A protein in rice bran which is not soluble in anything.</td>
</tr>
<tr>
<td>Bulk density</td>
<td>Weight per volume of material in bulk</td>
</tr>
<tr>
<td>Defatted rice bran</td>
<td>Rice bran from which most of the oil has been extracted</td>
</tr>
<tr>
<td>Phytin</td>
<td>Bran phosphorus existing in the form of Phytin</td>
</tr>
<tr>
<td>Chemical instability of Rice Bran</td>
<td>The process of fat hydrolysis in rice bran develops free fatty acids (FFA)</td>
</tr>
<tr>
<td>Solvent Extraction</td>
<td>Extraction of oil from oil bearing material by use of solvent such as Hexane or Alcohol</td>
</tr>
<tr>
<td>Pelletization</td>
<td>Process of forming pellets from rice bran</td>
</tr>
<tr>
<td>Dewaxing</td>
<td>Process of removal of wax from oil</td>
</tr>
<tr>
<td>Degumming</td>
<td>Process of removal of phosphatides from oil</td>
</tr>
<tr>
<td>Neutralization or Deacidification</td>
<td>Process of removal of FFA (free fatty acids) from oil</td>
</tr>
<tr>
<td>Bleaching</td>
<td>Process of removal of colour from oil</td>
</tr>
<tr>
<td>Deodorization</td>
<td>Process of removal of smell from oil</td>
</tr>
<tr>
<td>Winterization</td>
<td>Process of removal of saturated glycerides from oil</td>
</tr>
</tbody>
</table>

### 13.8 SOME USEFUL REFERENCES

1. Bor S.Luh, S.Barber and C.Benedito de Barber, Rice Bran: Chemistry and Technology, New York, USA
2. B.O Juliano, Rice: Chemistry and Technology, edited by B.O Juliano, American Association of Cereal Chemists, St. Paul, Minnesota, USA,
3. J.A. Cornelius, Rice bran oil for edible purposes: A review, Tropical Science, Volume 22, No. 1
4. Hand Book on Rice Bran, The Solvent Extractors’ Association of India, Bombay,
6. S.Barber and C.Benedito de Barber: Chemistry and Technology, Rice Production and Utilisation, edited by B.S. Luh, AVI Publishing Co., Westport, Connecticut, USA,
7. S.Barber and C.Benedito de Barber, Rice Bran: An Under-Utilized Raw Material, United Nations Industrial Development Organization, Vienna,
13.9 ANSWERS TO CHECK YOUR PROGRESS

1. Rice bran is the hard outer layer of rice grain and consists of combined aleurone and pericarp. It is a by-product of milling process. It contains various antioxidants, oil, dietary fibre, starch, protein, vitamins and dietary minerals.

2. About 5 Kg of bran is obtained after milling one quintal of paddy.

3. Bran composition is affected by stage of polishing and number of polishers used during process.

4. Rice protein consists mostly of insoluble glutelin (about 80%) and small amount of albumin.

5. True density of rice bran is about 1.2 to 1.3 gm/cc and its angle of repose is 38 degrees.

6. Rice bran is used for extraction of protein, extraction of oil, human food and as animal and poultry feed.

7. Refining of crude rice bran oil involves the following steps:
   (i) dewaxing
   (ii) degumming
   (iii) neutralization or deacidification
   (iv) bleaching
   (v) deodorization
   (vi) winterization
UNIT 14 RICE HUSK

Structure
14.0 Objectives
14.1 Introduction
14.2 Structure, Composition and Properties
   14.2.1 Rice Hull Structure
   14.2.2 Composition and Properties
14.3 Husk as Fuel
14.4 Types of Furnaces and Combustors
   14.4.1 Combustion
   14.4.2 Types of Furnaces
   14.4.3 Inclined Step Grate Furnace
14.5 Husk Based Boilers
14.6 Gasification
14.7 Nature of Ash and Its Uses
   14.7.1 Rice Husk Ash
   14.7.2 Uses of Both Type of Husk Ash are Given Below
14.8 Other Specified Uses of Rice Husk
14.9 Let Us Sum Up
14.10 Key Words
14.11 Some Useful References
14.12 Answers to Check Your Progress

14.0 OBJECTIVES

After reading this unit, you should be able to:

- state various properties of rice husk;
- explain combustion and gasification of rice husk; and
- know the various industrial uses of rice husk and ash.

14.1 INTRODUCTION

The large amounts of unusable husks often prove to be an expensive liability to a rice mill rather than an asset. Since the large scale industrial consumption of husk does not seem immediately promising, the economical use of the husks in the rice mill is appropriate and recommendable. The rice mills require heat energy for drying raw as well as parboiled paddy.

One fifth of paddy by weight consists of husks and makes up the largest milling by-product of rice. The commercial utilization or useful consumption of husks will have a major impact on economics of the rice milling industry owing to the world-wide energy crisis.
The physical characteristics of husk often present problems for its commercial utilization. The husks are fragile and porous and therefore, have low bulk density. No other agricultural residue even approaches the amount of silica found in husks (about 15-18 percent); as a consequence husks are very abrasive in character. They are low in nutritional value and add very little to the soil as fertilizer.

Rice husks have a variety of industrial uses which are described in detail as under. However, the profitable utilization in relation to its overall production is very small in practice.

14.2 STRUCTURE, COMPOSITION AND PROPERTIES

14.2.1 Rice Hull Structure

The rice hull constitutes from 18 to 28 per cent (average 22 percent) of rough rice mass. The hull, harsh woody covering around the kernel consists of two interlocking halves. The larger of the two halves is the flowering glume or lemma; the smaller one is the palea. The outer tip of lemma may be extended into needle shape bristle known as awn; however in some variety this is either small or vestigial. Outer surface of lemma and palea contain short stiff hairs. The lemma overlaps and interlocks with the palea contain short stiff hairs. At the base of the grain separated from the flowering glumes by a short section of rachilla are two sterile glumes. All these components appear in the commercial hull fraction, but the flowering form the predominant material.

14.2.2 Composition and Properties

In general, on an average 100 kg of paddy will generate 20 kg of hulls. Short grain varieties produce slightly more hull than medium or long grain varieties. The composition of rice hull is given in table 14.1.

Rice hull has the lowest content of protein and available carbohydrates and the highest content of crude fibre, crude ash, and silica. These factors make rice hull less digestible nutrients, less than 10%.

The main carbohydrate components of rice hulls are cellulose and lignin. Lignin, which is high in rice hull, gives the plants rigidity and binds the cells together. The water-repellent outer covering of rice hull (cutin), amounts to 2.1 to 6% of the hull.

Table 14.1: Composition of rice hull

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Percent range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>9.8-11.0</td>
</tr>
<tr>
<td>Crude protein</td>
<td>2.9-3.6</td>
</tr>
<tr>
<td>Cellulose (fibre)</td>
<td>41.1-43.0</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>24.7-28.0</td>
</tr>
<tr>
<td>Ash</td>
<td>15.7-18.2</td>
</tr>
</tbody>
</table>

Rice hull has a less bulk density and true density of about 0.1 – 0.16 g/cm³ and 0.67 – 0.74 g/cm³ respectively. Hull can be readily compressed to about 0.4 g/cm³ and grinding increases bulk density of 0.1-0.2 g/cm³, since the three dimensional structure of it is preserved during ashing.

Thermal conductivity of rice hull is 0.0359 W/m °C is very less and can be used as excellent insulating material. Angle of repose of rice hull is 35° and for ground hull it is 43-45°.
Rice hull contains 16 to 22% ash, and 90-96% of the ash is composed of silica. Therefore, rice hull ash is considered a slightly impure form of silica. Because of high silica content in rice hull (21-22%), the energy content of rice hull is lower than 11.9-13 MJ/kg at 14% moisture. The higher the ash content of rice hulls, the lower the calorific value.

Highest silica content and structure of rice hull makes it very abrasive in character. Metal surfaces in frequent contact with rice hulls will wear out and eventually puncture.

Rice hulls contain only minor levels of potassium and chlorine, and therefore ash melting temperatures of rice hull are much higher than those of rice straw. Thus, you have fewer problems of “slag” (molten glass) deposits when hull rather than straw is used as a fuel.

Check Your Progress 1

Note: a) Use the spaces given below for your answers.
   b) Check your answers with those given at the end of the unit.

1. What are the terms lemma, palea and awn refer to?

2. Explain nutritive content of rice husk?

3. Why rice husk is abrasive in nature?

4. Can rice husk be used as insulating material? Why?

5. How much is the bulk density of rice husk?

14.3 HUSK AS FUEL

Rice husk can be used as fuel by combustion in excess air and in a controlled atmosphere, by pyrolysis, by gasification-(producer gas) and by other chemical and thermo-chemical and biological process. Rice husk has calorific value of 12.55 MJ/kg in comparison to wood 25.1 MJ/kg, coal 29.29-37.65 MJ/kg, and diesel 41.84 MJ/kg etc. Therefore 1 kg of wood will give energy equivalent to 2 kg of husk and similarly 1 kg of coal is equivalent to 3 kg of husk.
Rice husk is used as fuel for steam generation in boilers for rice mills and parboiling plants. As explained above the conversion of rice husk to heat energy is obtained by different thermo-chemical process. Combustion takes place in furnaces and gasification in gassifiers. In furnaces the heat energy generated is used for steam generation in the boilers, where as gassifiers produce a combustible gas to provide heat or generates a fuel gas which can be used in an internal combustion engine as petroleum substitute. The detail description of the furnaces, boilers attached with the husk fired furnaces and the process of gasification is given in the subsequent sections.

14.4 TYPES OF FURNACES AND COMBUSTORS

14.4.1 Combustion

Conversion of rice husk to heat energy must be done in a reactor known as furnace by the process of combustion. Fuel burned in sufficient amount of oxygen, releases large amount of heat, because of the oxidation of the combustible constituents (viz. carbon, hydrogen, etc.). This process is known as combustion. On combustion of the fuel first moisture is given off, then volatile matter is liberated, and finally the ash. All the incombustible mineral matter in the fuel is lumped together to be known as ash. It is mainly consists of oxides of silicon’s, iron and aluminum.

To burn a fuel efficiently, four basic conditions must be fulfilled.

1. supply of enough air for complete combustion of fuel
2. secure enough turbulence for through mixing of fuel and air
3. maintain the furnace temperature high enough to initiate the incoming air fuel mixture, and
4. provide enough furnace volume to allow time for combustion to be completed.

The theoretical quantity of air required for complete combustion of fuel can be computed by the following equation if ultimate analysis of fuel is known.

\[
\text{Mass of air required per kg of fuel} = 11.5 C + 34.5 \left( H - \frac{O}{8} \right) + 4.35 S
\]

(1)

Ultimate analysis of solid fuels gives the chemical constituents of the fuel such as carbon (C), hydrogen (H), sulphur (S), nitrogen (N), moisture (M) and ash (A) expressed as fraction fractions of moisture free basis of fuel.

\[
C + H + S + N + M + A = 1
\]

If the ultimate analysis of paddy husk is \( C = 31\% \), \( H = 4\% \), \( O = 16\% \) and \( S = 0.7\% \). Then the mass of air required for complete combustion of husk under ideal condition is determined from the equation (1)

\[
= 11.5 \times 0.31 + 34.5 \times \left( 0.04 - \frac{0.16}{8} \right) + 4.35 \times 0.007 = 4.285 \text{ kg}
\]

i.e. for complete combustion of 1 kg of husk 4.3 kg of air is ideally required.

However, more supply of theoretical air does not secure complete combustion of the fuel due to improper mixing of air and in case of combustion of solid fuels. The amount of excess air depends on the type of fuel and method of burning. Normally 30 to 50 \% excess air is supplied in efficient furnaces but values of 60 to 70 \% excess air is also common for low heat value fuels like paddy husk.

14.4.2 Types of Furnaces

There are several types of furnaces with fundamental differences. They include fixed bed flat grate, inclined step grate and movable inclined step grate, fluid bed air suspended gas combustor and cyclone furnace.
14.4.3 Inclined Step Grate Furnace

Traditional method of burning husk is an inclined step-grate furnace with a vibratory feeder or any method of ensuring sealing of air and desired metering of husk feed. The diagram of floor level inclined step grate furnace is shown in figure 14.1. The husk is fed into the internal furnace chamber of a boiler pneumatically or manually (1, 2). Transport air for kg of husk is in the range of 3.744 m$^3$. For kg of husk for proper combustion 5.928 m$^3$ of air is required. The additional air is supplied by induced draft (mechanically by using a fan) or natural draft (by using chimney) (7). To reduce the temperature of the flue gas to the desired level ambient air is allowed to the mixing chamber through port (8). There are several variations in style with emphasis on the special form of the grate bars and proper inclination of the step grate. Very important is the necessary to have a uniform draught through the grate (not more than 1 m/s) and therefore a uniform porosity of the layer of husk and desired products further down the grate.

![Diagram of floor level inclined step grate furnace](image)


Fig. 14.1: Floor level inclined step grate furnace

14.5 HUSK BASED STEAM BOILERS

A boiler is a device to generate and supply steam at desired temperature and pressure. The boilers are installed in industries to supply process heat and in power stations to generate electricity. In rice processing plants, the boiler performs both these functions i.e. it supplies steam for parboiling of paddy and heat the air in a steam heat exchangers for drying of paddy and also develop mechanical power to operate the rice mills and other processing equipments in the processing complexes.

In rice mills use of paddy husk, a byproduct of the rice mill as fuel for steam generation in boiler is the most common and popular. One of the best examples of beneficial use exists in India, where 60% of the total husk available nationally is used as source of energy for parboiling and drying.

The efficiency of the industrial boiler with husk fired furnace for steam generation ranged in between 50-60%. The major loss is due to the energy carried away by the exhaust flue gases leaving through the chimney. The gases from fuel combustion cannot be cooled to air temperature in the boiler room and therefore all the heat which is released by the combustion of the fuel cannot be reused.

Boilers are broadly classified as:
1. Fire tube boilers and
2. Water tube boilers

Fire tube boilers are further classified into smoke, fire tube and combustion tube boilers. A smoke or fire tube boiler would be a combustion tube type if the fuel enters the tube section in a partially or totally unburnt condition.

In smoke tube boiler, all combustion is completed within the furnace. There is no ash beyond the furnace curtain wall.

In a fire tube boiler some burning of gases occurs within the tube area but all the fuel is converted to gas before entering the tube. This includes boilers of external furnace.

In combustion tube boilers some or all of vaporization occurs within the tube lengths. There is an overlapping area of the furnace, ash removal system and their effect on the distribution of fuel and ash. The most efficient combination is a matched furnace and boiler where in the boiler tubes and gas flow are matched to the desired performance of the furnace. Figure 14.2 shows the fire tube boiler with husk fired furnace

### Table 14.2: Performance of a multi pass fire tube boiler

<table>
<thead>
<tr>
<th>Evaporation capacity at 100°C kg/h</th>
<th>Heating surface m²</th>
<th>Grate area m²</th>
<th>Husk consumption kg/h</th>
<th>Empty weights (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Boiler</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>500</td>
<td>19</td>
<td>1</td>
<td>200</td>
<td>6</td>
</tr>
<tr>
<td>750</td>
<td>39</td>
<td>1.5</td>
<td>300</td>
<td>8</td>
</tr>
<tr>
<td>1000</td>
<td>55</td>
<td>2</td>
<td>400</td>
<td>10</td>
</tr>
<tr>
<td>1500</td>
<td>75</td>
<td>3</td>
<td>600</td>
<td>12</td>
</tr>
<tr>
<td>2000</td>
<td>100</td>
<td>4</td>
<td>800</td>
<td>14</td>
</tr>
<tr>
<td>2500</td>
<td>125</td>
<td>5</td>
<td>1000</td>
<td>16</td>
</tr>
</tbody>
</table>

![Fig. 14.2: Fire Tube Boiler with Husk Fired Furnace](image-url)
Gasification is the thermal decomposition of organic material at elevated temperatures in an oxygen restricted environment. The process, which requires an initial heat supply to get underway, produces a mixture of combustible gases (primarily methane, complex hydrocarbons, hydrogen and carbon monoxide). This producer gas can then either be used in boilers or cleaned up and used in combustion turbines or in generators. The gasification process is either self sustaining once the operating temperature is reached or it can be maintained by recycling a small proportion of the energy produced from the combustion of the fuel gases.

**Fig. 14.3: Process flow diagram for Gasification**

The process flow diagram for Gasification is shown in Figure: 14.3 (the diagram for pyrolysis being remarkably similar). Thermal pyrolysis is only different from the gasification process in that the thermal decomposition takes place in the absence of oxygen. The only necessary modifications to the gasification process diagram are that there will be no air input into the pyrolyser which will result in the creation of an energy rich oil and combustible solid residue (known as char) together with the fuel gas.

When comparing to mass burn, there are several clear advantages: It can be a more efficient technology. Biomass gasifier has a 36% efficiency compared to 21% for mass burning. The major environmental benefit of these processes are that they retain pollutants (the sulphur, heavy metals etc.) in the ash instead of them being moved to the gas phase and discharged to the atmosphere. Therefore the emissions from this technology are much lower than produced by conventional incineration and will require less flue gas treatment. In fact, there is often no need for a smoke stack as the emissions only come from the burning combustible gases in a turbine or boiler.

One disadvantage with the process is the necessary fuel preparation. The fuel material is required to be shredded before being fed to the gasifier, which entails cost. However, with the savings made by not requiring the level of emission controls, the process can prove economically profitable. The major drawback to these systems is with getting past the planning stage. Advanced thermal technologies like these are still categorised as incineration when it comes to planning. The public generally have misconceptions as to the word "Incineration" as most expect huge visual intrusion and dangerous smoky emissions. This is the reason why the granting of planning permission is often resisted by the local community. The absence of a smokestack, however should help with planning permission applications.

**Types of Gasifiers**

**Fixed Bed Gasifiers**

*Updraft Gasifier (UDG):* Biomass enters through a lock-hopper and flows down against the flow of blast and generated gas. The counter flow arrangement is more
tolerant to biomass moisture (up to 40 or 50% M) because drying occurs with produced gas, but the gas is loaded with tar (>5% to 10% tar), so it is usually only useful for staged combustion. The dirty product gas of the UDG means that it is not applicable for most applications that require clean gas, such as synthetic fuel, chemical or gas turbine applications. These are best for heat only applications, such as boiler firing.

**Downdraft Gasifier (DDG):** Biomass enters through an open top in an air-blown system or through a lock-hopper in an oxygen-blown system. The open top DDG design is simple and low-cost. Gas suction is required for operation, which is why it works well with internal combustion engines for small-scale power generation. The counter flow arrangement gives discrete zones of pyrolysis (flame front) and char gasification. Biomass and main pyrolysis air enter through the top with generated gas and char exiting the reactor at the bottom. Adding blast to the char zone is an excellent approach for achieving low tar gas (<100 mg tar/Nm³). In effect, this is a two-stage gasifier with a plug flow reactor configuration, which is why tar production is often very low. The downdraft gasifier is useful for small scale applications, and may have a practical upper limit of 1 to 1.5 MW (or 40 to 48 inch diameter.)

**Fluidized Bed Gasifiers**

**Bubbling Fluidized Bed (BFB):** The BFB gasifier is well known and commonly used because of its reliable performance, isothermal operation, and suitability to large scale application. The fluidized bed gives rapid heating of reactant gases in addition to excellent mixing of biomass solids and inert media. The inert fluidizing media is typically comprised of silica, mullite, or olivine sand, and contributes substantial thermal ballast during startup and operation, which lends to its stable operation. Air, steam or oxygen blends are delivered through a flow distributor (perforated plate/cone or manifold array) into a fluidized bed of sand. Biomass is delivered into the bubbling bed via an auger from an air-locked hopper. Tar production is moderately high at 1% to 2%, but less than a fixed bed updraft gasifier. The fluid bed has less than ideal tar production because of internal gas bypassing via the bubbles in the bed and because devolatilization may be occurring uniformly through the emulsion of gas and solid particles (much like an idealized well mixed reactor), therefore tar slip does occur. In any case, the BFB is quite robust for both pyrolysis and gasification, but secondary processing of the generated gas may be required for more critical applications besides strictly thermal energy supply.

**Circulating Fluidized Bed (CFB):** The CFB gasifier has no distinct interface between the dense phase of fluidized sand and the freeboard (dilute particle phase). In fact the higher velocity fluidization regime means that there is a particle density gradient from the bottom of the gasifier to the top. Entrained media and char fines are recycled back to the gasifier via a retention cyclone. The higher velocity regime gives an alternative approach to increasing char residence time to promote higher efficiency gasification. However, detailed studies show similar carbon conversion limits in a CFB Gasifier (92%) compared to a BFB Gasifier. Alternative design approaches are being considered at various research institutions, however, to improve carbon conversion through staged oxidation within the reaction column.

**Entrained Flow**

Entrained flow gasifiers are commonly used for coal because finer particle sizes and higher operating temperatures can be achieved to achieve complete conversion. However, entrained flow gasifiers are not practical for biomass for several reasons including operating temperature limiting properties of biomass ash and the impracticality of generating finely ground biomass feedstock. Biomass also has a high porosity (lower energy density) and higher moisture holding capacity, which makes it impractical to slurry feed biomass—a common approach for solids feeding to high pressure for most commercial coal gasifiers.
Check Your Progress 2

Note: a) Use the spaces given below for your answers.
   b) Check your answers with those given at the end of the unit.

1. Give the calorific value of rice husk, coal, wood and diesel?

2. Define combustion?

3. What are the conditions to burn a fuel efficiently?

4. State different type of furnaces?

5. In rice processing plants, what are the two functions that a boiler can perform?

6. What is gasification?

7. Draw the flow diagram of gasification process?

8. What is the difference between gasification and pyrolysis?
9. What are advantages and disadvantages of gasifiers?

...................................................................................................................................

...................................................................................................................................

14.7 NATURE OF ASH AND IT USES

14.7.1 Rice Husk Ash

When rice husk is burnt for energy production or disposal, resulting as is an important byproduct for many industrial applications.

Composition:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>95.00%</td>
</tr>
<tr>
<td>CaO</td>
<td>0.70%</td>
</tr>
<tr>
<td>MgO</td>
<td>0.015%</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.09%</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.00%</td>
</tr>
<tr>
<td>MnO₂</td>
<td>0.05%</td>
</tr>
</tbody>
</table>

Main constituent of ash is silica. Depending on type of combustion process ash varies from high carbon char to a carbon free white ash. If temperature of combustion is very high (1000 to 1200 °C) mostly black ash is produced and if husk is burnt slowly at low temperature carbon free white ash is produced.

14.7.2 Uses of Both Types of Husk Ash are Given Below

1) Oil absorbent: Micro porous structure of silica in ash causes absorption of oil by it. Ash is used as grease-sweep for removing oil stains and for cleaning floors in petrol pumps, kitchens, oil refineries etc.

2) Washing powder: White ash mixed with 10 to 25% washing soda and ground to powder produces a product similar to “Vim Powder” popular domestic cleaning powder. This application has good potential in India.

3) Water purification: Black ash or husk char is used as filter medium for purification of water.

4) Filler material in rubber compounding: White ash is used as reinforcing agent in compounding of rubber in place of carbon black.

5) Rice husk cement: White carbon free husk ash mixed with slaked lime Ca(OH)₂ and Portland cement. Husk cement may be used in plastering, lining of canal walls for preventing seepage, making building blocks and as cement mortar for laying of bricks.

6) Sodium silicate: Sodium silicate is produced by chemical reaction of white ash with caustic soda as shown in following reaction.

\[
\text{SiO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}
\]

Sodium silicate is a base material for many chemical products such as precipitated silica, silane, silicon tetra chloride and finally solar grade silicon. Sodium Silicate has good binding properties and is used in manufacture of straw board.
Check Your Progress 3

**Note:**

a) Use the spaces given below for your answers.

b) Check your answers with those given at the end of the unit.

1. Give the composition of rice husk ash?

2. Explain white and black ash?

3. How the rice husk ash is useful?

---

**14.8 OTHER SPECIFIED USES OF RICE HUSK**

Some other uses of rice husk are given below

1. **Use of rice husk as admixture in animal feed**

The average composition and digestible nutrients of rice husk is given in Table 14.3.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dry matter</td>
<td>92.0</td>
</tr>
<tr>
<td>Digestible protein</td>
<td>0.1</td>
</tr>
<tr>
<td>Total digestible nutrients</td>
<td>9.9</td>
</tr>
<tr>
<td>Average total composition</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>3.0</td>
</tr>
<tr>
<td>Fat</td>
<td>0.8</td>
</tr>
<tr>
<td>Fibre</td>
<td>40.7</td>
</tr>
<tr>
<td>N- free extract</td>
<td>28.4</td>
</tr>
<tr>
<td>Mineral matter</td>
<td>19.1</td>
</tr>
</tbody>
</table>

Though rice husk has a low nutritive value, in many countries they have been used as an admixture in cattle feed. In order to soften the husk to increase the digestible protein, husk is ammoniated with anhydrous ammonia at raised temperature and pressure in the presence of monocalcium phosphate. The use of husk is considered inadvisable in Italy. The husk is prohibited in Spain.
2. Use of Rice husk as a Mulch soil conditioner

In many countries a large amount of husk are returned to the land for purpose of soil conditioning. Rice husk used mulch for growing cotton (Australia), rice (Japan), onions (Philippine), and vegetable and flowers (Thailand). In the Sacramento Valley of California, most of the husk is deposed off by ploughing directly into the soil. Rice husk is also used as an admixture in some fertilizers, even though it adds very little N, P or K value to the product.

As a mulch, rice husk retains water and tend to keep the soil moist. As an admix, rice husk helps preventing the caking of fertilizer and also tends to make the soil condition higher. The agriculture extension service of University of California, Davis, carried out a study of 100 tonnes of ground husk per acre of heavy soil resulted in a highly significant depression in the rice yield. The study neither proved nor ruled out the possibility of nitrogen immobilization or chlorine-nitrogen interaction due to the husk decomposition.

3. Use of husk for the production of Furfural

Commercial furfural is a pale yellow liquid with the odour of almonds and is obtained from agricultural residues namely, corns, cotton seed husks and rice husks. Furfural is extensively used as selective solvent in purifying lubricating oil, diesel oil, wood resin, and vegetable oils. Furfural is also used as a selective solvent in the extrication, distillation for the separation and purification of carbon, hydrocarbons in connection with butadiene production. Recently furfural found other uses as a plasticizer for automobile manufactured parts, disinfectants, fungicides and bactericides. Furfural when thickened with starch becomes a satisfactory paint and varnish removal. The latest, and possibly the largest use, of furfural is a chemical, intermediate products such as furon, tetrahydrofurfural, alcohol, methyletetrahydrofuron, etc.

4. Use of rice husk to produce cellulose and pulp

Rice husks were investigated as a possible raw material for making paper. The alpha-cellulose content of husk is comparatively very low and fibre is very short. The northern regional laboratory of USDA evaluated the cellulose pulp made from husk and concluded that the fibres are too short to contribute any strength properties to paper. Rice husk also have a low bulk density and require a large amount of chemical for reduction to fibre. The mechanical processing is non competitive with that for wood pulp.

5. Use of rice husk as admixture in building materials

In an effort to explore new uses of husk it was investigated the possibility of using husk in building materials. Density of fifteen different mixtures of husk, rice husk concrete ranged from 1095 kg/m³ to 1745 kg/m³ as compared with 2380 kg/m³ for sand gravel cement concrete. In general, when the volume of total aggregate to cement is constant, the compressive strength is affected by the ratio of rice husk ash to rice husk. The investigator concluded that the concrete made did not have adequate strength and stability at a competitive cost with the sand-gravel-cement concrete, though it had higher insulating value than ordinary concrete.

The use of husk as an aggregate in light weight concrete blocks or bricks has also been tried at Tropical Products Institute of United Kingdom. The blocks were made of a mixture of husk, cement and water, and were reported to have survived a cold winter with no deterioration. The institute is of the opinion that the husk can be successfully used as an admixture in light weight concrete blocks if care is exercised in the preparation of the mix and if pressure moulding is practiced.

6. Use of rice husk as insulating material

Rice husk have been used as loose insulating material in buildings, farm structures and cold storage plants in many countries. The loose fill of husk between interior and exterior walls represent a fire hazard unless treated with borax and boric acid for flame proofing.
Husk, as with other loose fill materials must be sealed with effective vapour barrier to prevent condensation of moisture with the material under various ambient and environmental conditions.

Rice husk have also been used effectively as packaging material for the protection of eggs, fruits, china-ware and other fragile commodities from damage during handling and transportation. The advent of foam plastics and the availability of wood wool and shavings have, however, limited the use of husk for packaging materials.

7. Use of rice husk in hard panel board

Recently the use of husk in panel and composite boards based on modern day technology has proved economically advantageous. The physical characteristics of panel board vary from the very hard, high density particle boards to the soft pulp like panels becoming upon their intended use. Some panel boards are intended for exterior use, some for interior use only; some as wall boards, floors or ceilings. It is technically feasible for husk for manufacturing of many of these boards and the cheaper methods are being developed.

8. Use of rice husk as filler

Many investigators have given consideration to the use of ground husk as filler for phenolic resin wood adhesives, plastics and animal glues. The rice husk was decomposed by means of alkalis for preparing gel. The residue after alkali decomposition consisted mainly of cellulose, proteins and pentosons. The extract was acidified to form a gel which was claimed to be excellent filler for phenolic resin and animal glues.

9. Dry distillation of rice husk to produce chemical and charcoal

The charcoal and chemicals like acetic acid, methanol and tar can be produced from husk by dry distillation. When agricultural wastes or wood is heated in absence of air to about 315 °C, spontaneous decomposition with a generation of heat takes place. The residue is charcoal and the vapours on condensation results in a gas of low calorific value and the water solution. This water solution on distillation can be separated into methanol, acetic acid and tar. The product obtained by destructive distillation of rice husk is shown in table 14.4

<table>
<thead>
<tr>
<th>Table 14.4: Products obtained by destructive distillation of rice husk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product</strong></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Liquor</td>
</tr>
<tr>
<td>Charcoal</td>
</tr>
<tr>
<td>Acetic acid</td>
</tr>
<tr>
<td>Methonal</td>
</tr>
<tr>
<td>Acetone</td>
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<tr>
<td>Loss (by difference)</td>
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</table>

The charcoal thus formed, was finely divided and difficult to remove from the process. The methanol and acetone are produced in synthetic plants at a lower cost. This rendered the use of rice hulls uneconomical. Despite the early investigation on the preparation of charcoal and active carbon from rice husk, there has not been large scale consumption of rice husk for these products.
Check Your Progress 4

Note: a) Use the spaces given below for your answers.
   b) Check your answers with those given at the end of the unit.

1. What are the uses of rice husk?

14.9 LET US SUM UP

The large amounts of unusable husks often prove to be an expensive liability to a rice mill rather than an asset. Disposal of this low value by product poses a serious problem because of its abrasive characteristics, low nutritive value, low bulk density, and high ash content. Since the large scale industrial consumption of husk does not seem immediately promising, the economical use of the husks in the rice mill is appropriate and recommendable.

Rice husk can be used as fuel by combustion in excess air and in a controlled atmosphere, by pyrolysis, by gasification (producer gas) and by other chemical and thermo-chemical and biological process. Rice husk has calorific value of 12.55 MJ/kg in comparison to wood 25.1 MJ/kg, coal 29.29-37.65 MJ/kg, and diesel 41.84 MJ/kg etc. Therefore 1 kg of wood will give energy equivalent to 2 kg of husk and similarly 1 kg of coal is equivalent to 3 kg of husk.

Rice husk can also be used as admixture in animal feed, as a mulch soil conditioner, for the production of Furfural, to produce cellulose and pulp, as admixture in building materials, as insulating material, in hard panel board, as filler material and to produce chemical and charcoal etc.

14.10 KEY WORDS

- **Combustion**: Process of release of heat by exothermic heat of reaction by oxidation of combustible constituents in the fuel
- **Gasification**: is the thermal decomposition of organic material at elevated temperatures in an oxygen restricted environment
- **Boiler**: is a device to generate and supply steam at desired temperature and pressure
- **Pyrolysis**: is thermal decomposition of organic material at elevated temperatures in the absence of oxygen.

14.11 SOME USEFUL REFERENCES


14.12 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress Exercise 1

1. The hull, harsh woody covering around the kernel consists of two interlocking halves.

   The larger of the two halves is the flowering glume or lemma; the smaller one is the palea.

   The outer tip of lemma may be extended into needle shape bristle known as awn.

2. Rice hull has the lowest content of protein and available carbohydrates and the highest content of crude fibre, crude ash, and silica.

   These factors make rice hull less digestible nutrients, less than 10%.

3. Highest silica content and structure of rice hull makes it very abrasive in character.

4. Yes, because thermal conductivity of rice hull is very less (0.0359 W/m °C)

5. 0.1- 0.16 g/cm³

Check Your Progress 2

1. Rice husk - 12.55 MJ/kg, wood 25.1 MJ/kg, coal 29.29-37.65 MJ/kg, and diesel 41.84 MJ/kg etc.


3. • supply of enough air for complete combustion of fuel,
   • secure enough turbulence for through mixing of fuel and air,
   • maintain the furnace temperature high enough to initiate the incoming air fuel mixture,
   • provide enough furnace volume to allow time for combustion to be completed.

4. fixed bed flat grate, inclined step grate and movable inclined step grate, fluid bed air suspended gas combustor and cyclone furnace.

5. • supplies steam for parboiling of paddy and heat the air in a steam heat exchangers for drying of paddy,
   • develop mechanical power to operate the rice mills and other processing equipments in the processing complexes.

6. Thermal decomposition of organic material at elevated temperatures in an oxygen restricted environment.

7.
8. Pyrolysis is only different from the gasification process in that the thermal decomposition takes place in the absence of oxygen.

9. Advantage:

   retain pollutants (the sulphur, heavy metals etc.) in the ash instead of them being moved to the gas phase and discharged to the atmosphere.

   Disadvantage:

   fuel preparation necessary

Check Your Progress 3

1. SiO$_2$ - 95.00%, CaO - 0.70%, MgO - 0.015%, Fe$_2$O$_3$ - 0.09%, Al$_2$O$_3$ - 0.00%, MnO$_2$ - 0.05%

2. If temperature of combustion is very high (1000 to 1200°C) mostly black ash (high carbon char) is produced and if husk is burnt slowly at low temperature carbon free white ash is produced

3. Oil absorbent, Washing powder, Water purification, Filler material in rubber compounding, Rice husk cement, Sodium silicate

Check Your Progress 4

1. As boiler fuel, as admixture in animal feed, as a mulch soil conditioner, for the production of Furfural, to produce cellulose and pulp, as admixture in building materials, as insulating material, in hard panel board, as filler material and to produce chemical and charcoal etc.
<table>
<thead>
<tr>
<th>Block No.</th>
<th>Unit No.</th>
<th>Print Material</th>
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<tbody>
<tr>
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<td>1</td>
<td>General</td>
</tr>
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<td></td>
<td></td>
<td>Production, Morphology, Composition and Utilization</td>
</tr>
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<td></td>
<td>2</td>
<td>Grades and Quality of Paddy and Rice</td>
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<td>2</td>
<td>3</td>
<td>Parboiling and Drying Principles</td>
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<td>Parboiling Principles and Practices</td>
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<td>3</td>
<td>7</td>
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<td>Storage Structures</td>
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<td>Plant Layout, Operation, Maintenance</td>
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<td>Rice Based Products</td>
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<tr>
<td>4</td>
<td>12</td>
<td>By-Products of Rice Milling</td>
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<tr>
<td></td>
<td>13</td>
<td>Rice Brokens</td>
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<tr>
<td></td>
<td>14</td>
<td>Rice Bran</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rice Husk</td>
</tr>
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