UNIT 13 REFINING OF COARSE GRAINS

Structure

13.0 OBJECTIVES

After reading this unit, you should be able to:

- explain the need for milling to get refined flours from coarse and minor cereals;
- state the principles of producing refined flours;
- explain the flow diagram for refining oats, sorghum, barley etc.,
- describe the machinery used for milling; and
- discuss the importance of crude fibre and ash and how they change upon milling.

13.1 INTRODUCTION

Maize, sorghum, oats, rye and millets form the important coarse and minor cereals. These cereals are well adapted to grow under a wide range of ecological conditions and are able to produce good yields even under unfavourable conditions. Their annual world production is about 550 million tonnes and India contributes 30 million tonnes to the basket. Maize, sorghum and millets in tropical countries and barley, rye and oats in temperate climates play an important role in the human diet. Although they account for only about 5% of world grain production, (4.6% of total starchy staples, on calories basis), they are extremely important in the semi arid zones where, frequently, little else can be grown. Some of the African countries derive one third to half of their cereal diet through sorghum and millets. Maize and sorghum account for nearly 80% of the total coarse grain production of cereals. These grains form staple food for a large segment of the population of India, Africa, Southern and Central America. In the developed countries, these grains are used mostly for feed and as industrial raw material.

Current methods of consumption of most of these grains are in the simplest forms. For food uses, coarse cereals and millets are generally pulverized in attrition mills on custom milling basis and a small portion of the coarse bran is sieved off. The small sized grits and flour are used to prepare various conventional food products depending on the food habits of the region. Unleavened pan cake (*roti*), dumpling (*mudde*), wet pancakes (*upmav*, *dosa*), leavened and steamed batter (*idli*) or porridge in the Indian sub continent, *masa* in Southern and Central America and *uji* and *ugali* in Africa are some of the prominent traditional foods prepared from these cereals. These cereals are also processed to prepare malt, popped or flaked cereals.

Nutritional profile of millets is far better than that of wheat, sorghum, or maize with respect to lysine and some other essential amino acids and the protective nutrients such as micronutrients, phytochemicals and dietary fibre. Even then, they are not being accepted by the entire section of the population due to their coarseness. Their consumption as food is limited only to economically weaker sections. They are not accepted by the richer classes of the population who are accustomed to softer grains like rice and wheat. However, with the growing awareness of the disease preventing and health beneficial aspects of coarse grains, there is an observable change in the pattern of consumption.

In marketing sorghum and millet products in competition with wheat products, there is no room for products that are less appealing. This often implies white, bright, uniform products without bran specks for the consumer and equally, high product yield for the miller. This calls for refining of the flour without losing too much of the health beneficial aspects. We shall discuss in some detail the need for refining, methods and machinery adapted for this process of refining.

13.2 NEED AND CONCEPT OF MILLING

As already discussed in the previous chapter, oats, rye and proso, kodo, foxtail, little and barnyard millets possess husk and bran similar to paddy, whereas, sorghum, maize, pearl millet and finger millet generally possess bran as the main seed coat and they resemble wheat.

Coarse and minor cereals are generally converted into whole meal flour before consumption. Since grains suitable for flour have a hard texture, considerable amount of energy and drudgery is involved in producing milled products suitable for cooking and consumption. The traditional equipment used for milling is the mortar and pestle and a stone hand mill (quern) consisting of a flat stationary stone and a movable stone. Care is taken to prepare the milled products and cook them freshly every day, because the keeping quality of the flour is low.

Simplest way of processing the coarse cereals is to grind the whole grain in the quern, sieve away the coarse bran particles and get about 90-95% of extraction of the product. Later on, the traditional hand mills were combined with the wheel in animal, water and wind driven horizontal stone mills consisting of two circular stones, one stationary and the other rotating. In these mechanically driven mills, grains were introduced in the center through the hollow axis. Spiral patterns engraved in the stones transported the milled material to the periphery, where the flour was collected for subsequent sieving and size grading.

However, the grinding process has been mostly mechanized by the introduction of small mechanically operated grinders. Hand cut stones have now been replaced by artificial stones made of carborundum disks and these units are now mechanically/ electrically driven. From these basic designs, vertical plate mills (*chakkis*) were developed, where the milling surfaces consist of cast iron or hard metal pieces. Traditional plate mills yield a coarse product. The power driven stone and plate mills function generally as custom mills. These units are not very costly. They are easy to operate and maintain. Therefore, they are extensively used.

Primary purpose of the milling step is first to reduce the coarse grains to their different botanical components which can be separated as cleanly as possible, either by sifting or aspiration or by both. The separated fractions such as the endosperm can then, if too coarse, be finely milled in another processing step with/without subsequent separation process, and rendered fit for consumption.

13.3 DEBRANNING – PRINCIPLES OF PRODUCING REFINED FLOURS

Cereal grains are a rich source of fiber. If the whole grain is ground, fibrous bran results in coarseness of the resultant flour. Coarse bran affects flour/dough quality, cooking quality and also the digestibility. For example, the storage proteins in grain sorghum are highly cross-linked and hydrophobic, which affect water absorption, processing and digestibility of the sorghum flour. Also, germ present in the grains is rich in lipids. If the whole grain flour is obtained, germ also gets pulverized and the fat content of the flour will be high. This is responsible for the poor shelf life of the flours.

Coarse grains are not being accepted by the entire section of the population for the following reasons:

- Coarse cereals and millets generally have a coarse, fibrous husk/bran. Fiber consists of endogenous components of plant materials that are resistant to digestion by enzymes in mono-gastric stomach and gastro-intestinal tract. The major individual components are cellulose, hemicellulose, lignin, pectins and gums mainly located in the pericarp and endosperm cell walls. Insoluble fiber components are present primarily in the pericarp. The outer most layers of bran/ glumes are fibrous, tough and irritating to the tongue.
- Their outer bran layers are also relatively resistant to water permeability rendering soft cooking in water very difficult. Even if the bran layers are removed, most of them have a subaleurone layer which is very hard and horny.
- Bran from most of the coarse cereals contains coloured pigments and also some anti nutritional factors. Polyphenols, phytic acid and goitrogenic components and galactose containing oligosaccharides are some of the antinutritional components present in them.
- These grains also have strong characteristic odour which may not be liked by all. Also, because of lack of gluten, thin rotis/ chapathis cannot be rolled.
- Whole grain flour of most of these cereals rapidly develops off-odors and off-flavors. For example, whole pearl millet flour becomes rancid within 6 to 10 days of storage and inedible after 11-14 days. The reasons for the rapid deterioration are: high lipid content, higher amounts of unsaturated fatty acids, insufficient naturally occurring anti-oxidants and high enzymatic-hydrolytic activity.

Therefore, palatability and shelf life are the two major requirements of products obtained from these grains. In order to reduce the deleterious effects of antinutritional factors, improve the flour quality and shelf life, coarse cereals and millets are subjected to the process of decortication/ refining.

In order to get the desired refined flours, it is necessary to remove the bran layers and/or germ partially, if not completely. Thus refining of coarse grains includes partial or complete debranning and degerming. Thus, decortication is the process of partial/complete removal of outer layers of the grains and germ. Therefore, decorticated or pearled kernels would have reduced levels of fiber, ash and fat.

13.4 SIMPLE GRINDING AND SIEVING

Coarse cereals and millets are processed into a wide array of food products, depending upon the food habits of the region. Invariably, this means that the grains are subjected to grinding for conversion to flour. Traditional method of hand pounding is still practiced in some parts of India and Africa. The traditional equipment is the mortar and a pestle or the stone hand mill. In the mortar and pestle system, grains are placed in the mortar and continuously pounded with the pestle. Resultant flour or semolina is sieved and overtails are returned to the mortar for further pounding. Sieves of various mesh sizes are used to obtain the flour particle size appropriate to the food product intended.

Simplest way of milling coarse cereals is to grind the whole grain in the quern, sieve away the coarse bran particles. The flour/ grits are subsequently sieved to remove the coarse bran particles.

In the machine driven units, artificial stones made of carborundum disks grains are used. Grains are introduced in the center through the hollow axis. Spiral patterns engraved in the stones transport milled material to the periphery. Gap between the stones is adjusted to grind the grains and the flour/grits are collected for subsequent sieving and grading.

Traditional plate mills (*chakkis*) consist of cast iron or hard metal disks. Gap between the plates is adjusted to get the required particle size of flour/grits. More commonly, whole grain is dry ground in these mills to grits, semolina or flour and the product is sieved to discard the bran. These mills yield flour containing about 50% particles sized less than 75 microns. Plate mills yield a coarse product compared to stone mills. After sieving off the bran after the first pass, relatively finer product with better colour and quality can be obtained.

Hammer mills are also employed for grinding. If used for production of whole meal flour, the product is sieved to remove the coarse bran.

The other method in the traditional milling set up is to moisten the grain before hand pounding. The moisture does not penetrate deep into the endosperm, since the grains are pounded immediately a few minutes after moistening, which facilitates the peeling of the pericarp from the endosperm. During the process of pounding, additional water might be added if necessary.

The pounded grains are sun dried for a few minutes and winnowed to separate the bran. These grains are washed in excess water and sun dried to obtain the desirable product. Here, although moistening facilitates easy removal of bran, it causes breakage of endosperm and affects keeping quality.

In general, traditionally milled products retain relatively more nutrients. Obviously, the manual methods are laborious and the capacities are too low. Quality of the resultant product is also not very good because of the high moisture content of the flour and mixing of the ground bran. However, flour products from mechanical methods are found to have better preference and they have improved shelf life.

The minor millets i.e., foxtail millet, proso millet and kodo millet must be dehulled before consumption. If mechanical milling is done properly on a large scale, beneficiation of by- products of milling can also be done. Pure bran from some of the millets also contains considerable proportion of soluble fiber. Hence, bran from those cereals also has potential utilization in therapeutic foods or pharmaceutical preparations. Bran from pearl and small millets, except finger millet, contains about 15% oil and this bran can serve as an extender to rice bran for oil extraction.

Traditional milling methods of coarse cereals and millets can be summarized as follows:

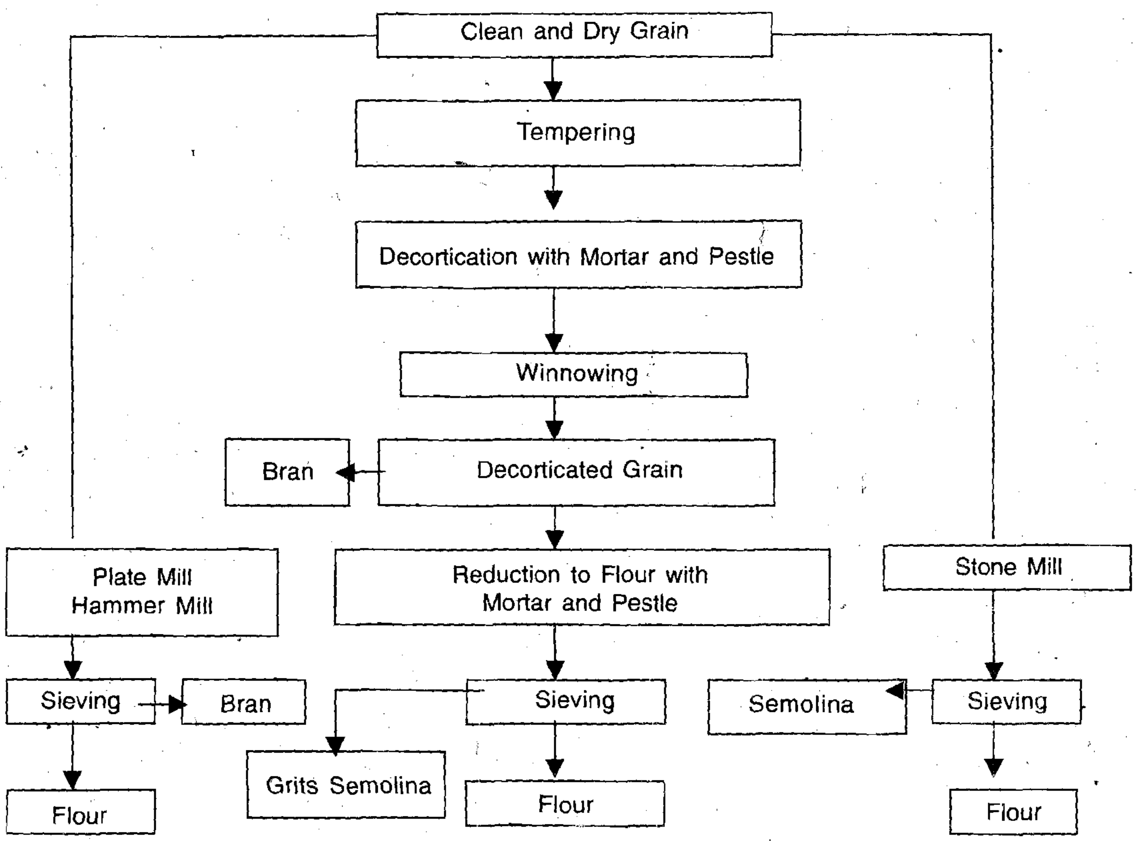

Fig. 1: Traditional milling methods of coarse cereals and millets

13.5 CONCEPT OF MOISTENING, GRINDING AND SIEVING

Purpose of the milling is to reduce the grain in such a way that the different botanical components can be separated as cleanly as possible, either by sifting or aspiration or by both. The separated fractions such as the endosperm can then, if too coarse, be then finely milled in a simple processing step without the need for a subsequent sophisticated separation process.

As already discussed, coarse grains need to be decorticated. Refining of coarse grains is achieved by removing the coarse, fibrous bran layers and also the germ, partially or completely. Incipient moist conditioning followed by pearling or grinding and sieving has been found to be practical to obtain low fiber grits and flour from most of these coarse cereals (Fig. 1).

It is often advantageous to condition them by adding water, mixing the mass thoroughly, followed by a resting period (tempering), before milling. Conditioning toughens the outer bran parts and the bran is rendered lather leathery. This makes it less prone to fine disintegration during milling, facilitating separation of the coarse bran particles from the endosperm, which due to its nature is more finely ground. Coarse bran can either be sieved off or aspirated.

Pioneering research work on refining of millets has been carried out at CFTRI, Mysore and it has been reported that incipient moistening and pearling in rice milling machinery debran these grains effectively and the food products prepared from the coarse cereals possess better consumer acceptability than that of whole meal flour.

Sorghum and millets are usually decorticated to remove 10 to 30% of the grain. Increased decortication causes increased losses of fiber, fat and ash. Fiber content in cereal products depends to a large extent on the degree of milling. It has been found that decortication slightly reduces protein and lysine content due to partial degermination. Nutrient digestibility of decorticated sorghum has been shown to be slightly higher than the native (parent whole) grains. Decortication of brown sorghums significantly reduces the condensed tannins and can therefore overcome their deleterious effects. Loss of nutrition during refining is also important and refining should be done judiciously not to lose the health beneficial factors.

13.6 EQUIPMENTS USED IN DEBRANNING

As already discussed, grinding equipment are being used for milling from time immemorial. Efforts have been made for mechanical debranning and milling to obtain decorticated grains as well as grits and flour. Both rice and wheat milling principles are adapted for milling coarse grains.

Mechanical forces are applied on the grains either by accelerating the grain against a metal surface (impact) or by utilizing the squeezing and shearing forces of rollers/ rotating discs or pressurized cylinders (attrition), where the grinding effects due to metal-to-seed, seed-seed surfaces would be operative.

A comparative evaluation has been made between the use of attrition and abrasive mills for decortication of coarse cereals and millets. It has been concluded that the abrasive mills are generally more suited for decortication as compared to attrition type mills.

Central Food Technology Research Institute (CFTRI), Mysore has developed a mini grain mill (Fig: 2) which could be used for the production of small sized grits, semolina and flour almost free from bran from maize, sorghum and millets. In this unit, an existing plate mill is attached with a water mixer, tempering cum hopper bin, a four-deck sieve and an aspirator system, all units deriving drive from a common motor.

Grains are fed into the main hopper and passed through a water mixer (2 to 5% water) and collected in the hopper of the plate mill. After about 5-10 minutes of

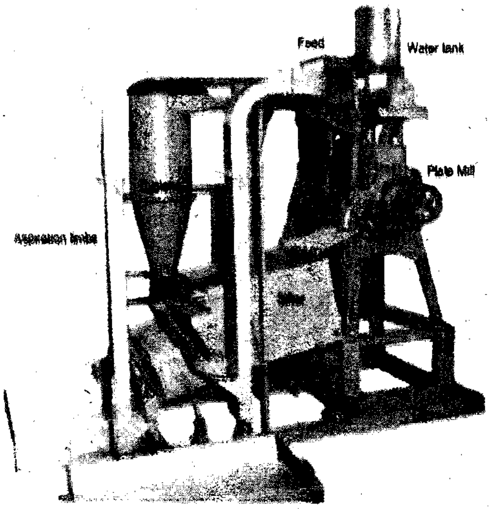

Fig. 2: Mini Grain Mill

tempering, grains are coarsely ground in the plate mill and the resultant milled fraction falls on the sifter deck by gravity. Coarse bran is separated on the top deck and other fractions viz., coarse, fine semolina and flour are collected separately. Pulverized bran coming out with the different fractions is also aspirated off.

The principles and milling systems followed for coarse grains can be broadly classified as follows:

1. Rice milling machinery followed by grinders
2. Roller milling systems, as in wheat milling
3. Attrition (friction) type mills
4. Abrasive type dehullers or
5. Combination of two or more of these systems

All these systems are dry milling systems. Some of these processes make use of pretreatment to grains such as moist conditioning, drying etc.

Large variations exist in the physical and morphological features among the coarse cereals; maize is the largest and some of the millets are the smallest of food grains. This calls for different milling equipment, different operating conditions and variety of milling techniques.

Special milling machineries have been developed for milling maize (debranning and degerming) whereas mills exclusively meant for millet milling have not been developed. But, dehusking and pearling of small millets could be done using shellers/ dehullers followed by pearling in engelberg hullers or the different types of polishers/ pearlers.

Let us now look into the milling of major coarse cereals and the flow diagrams for refining.

13.7 FLOW DIAGRAMS FOR REFINING

13.7.1 Milling of Oats

Utilization of oats is primarily in the area of food, feed and industrial uses. Even though the proportion of oats used for human consumption is less, its role in the overall human diet is a significant one. Its high nutritional value combined with its characteristic flavour helps it to secure an important place in the breakfast cereals group and other processed foods.

Quality and yield of milled products directly depend on the quality of the input stock. Ideally, oats should have low moisture content, clean (without other grains, discoloured kernel), high test weight (bulk density) and higher percentage of hulls.

Milling process of oats is very different from the rest of the cereal grains. This is primarily because of the following reasons:

- The hulls strongly adhere to the kernel or groat
- Oat kernels have very high fat content and should to be stabilized through heat treatment for prevention of rancidity
- The form in which it is consumed is also quite different from the other grains

Many different procedures can be used in the cleaning and processing of oats, and each processor, prefers ones own method. However, the milling process of oats begins with the cleaning. Cleaning is followed by grading before dehulling. Dehulling operation removes the hulls and the oat kernels without the hulls (groats) are sent for conditioning and drying. The conditioned groats are then graded and subsequently sent for cutting or flaking. Some of the material may also be ground and sifted for oat flour and bran production.

The sequence of operations in the modern oat processing plants generally can be summarized as follows (Fig. 3).

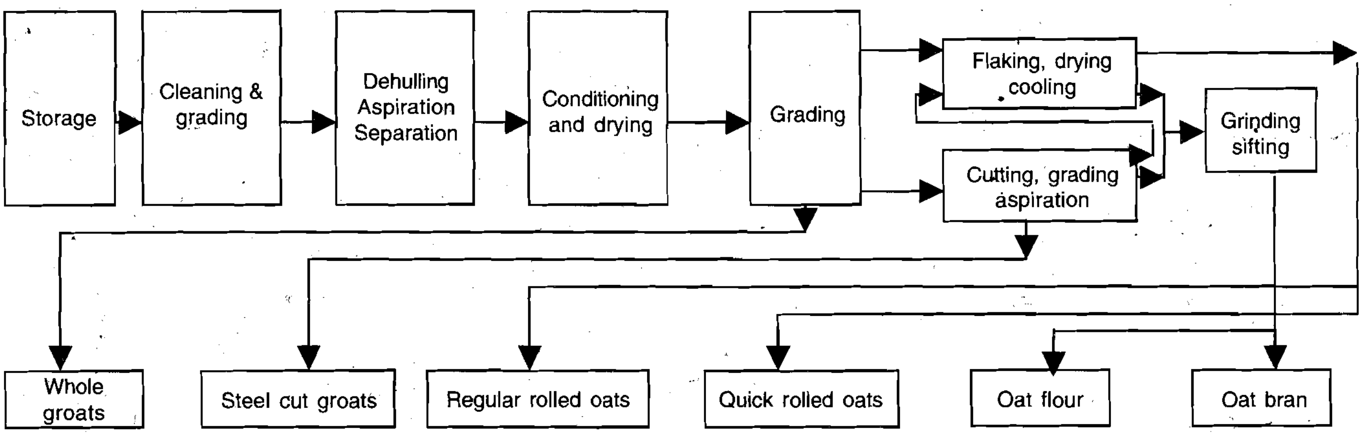

Fig. 3: A simplified block flow diagram of oat-milling process

Cleaning of oats includes a magnet for removal of ferrous impurities from the feed stock. Pre-cleaned oats received from the storage is subjected to mill cleaning at this stage. Mill cleaning generally involves more than one cleaning machine. A grain separator with air classifier is used to remove larger, finer and lighter foreign material from oats. The grain separator is followed by a destoner, where the stones, mud balls and other heavy material are removed. After size separation by sieves, the stock may pass through disk and indented cylinder type separators. A gravity separator for separating impurities that have different specific gravity than oat grains and a paddy separator to remove materials of equal size, shape and specific gravity, but with a different surface texture may also be in the mill line. In conventional old mills, grading is also carried out using grading sifters with different screen sizes to sort grains as small, medium and large ones. This is done to optimize the hulling efficiency.

The next cleaning machine in sequence could be a clipping machine. Apart from separating the double oats, this machine clips off the ends of oat kernels to improve the 'hullability' of the oats during the hulling operation.

Primary aim of the hulling operation is to remove the inedible hulls. If the moisture content of oats is higher it will be more difficult to hull. The ease with which the hulls can be removed from the oat kernel is referred to as hullability. Hulling operation aims at 100% dehulling with no or minimum brokens. Although these two points are attainable together up to a point, beyond that their relationship becomes inversely proportional. Therefore, in any dehulling operation, there will be some small percentage of unhulled grains as well as brokens.

Hullability is influenced by the following factors: moisture content of the grain, load on the huller, peripheral speed of the rotor, impact ring material and size of oats. Higher the moisture content, more difficult it is to remove hulls; however the broken percentage will be low. Higher the load on the huller, lower will be the dehulling percent – there will be higher proportion of unhulled grains remaining in the resultant material obtained after the hulling operation. Higher the peripheral speed, greater is the dehulling. However, the brokens will also be higher and the impact ring will also wear off sooner. Material composition of the impact ring affects the hulling percent, proportion of brokens produced and the life of the ring. Greater the uniformity of the oat grains better will be the dehulling results. This can be attained when oats are sorted out by size and sent to their respective hullers where the speed and load are set for the specific type.

Equipment used for dehulling

In the earlier days, hulling of oats was carried out by stone hullers. Dehulling in stone hullers used to demand lower moisture content of oats (which was necessitating kiln drying). But of late, impact dehullers have taken over the place of stone hullers. In the Impact dehulling method, Oats can be dehulled in their normal moisture range (12-14%) and the percentage of brokens created is very small in this moisture range; Kiln drying is not required and thus the cost factor associated with the drying operation is eliminated. Also, Impact dehullers require less horsepower. However, in some oat processing plants, use of drying before impact hulling is also followed, as this makes the hull brittle and the hullability improves.

A typical impact huller is shown in Fig. 4:

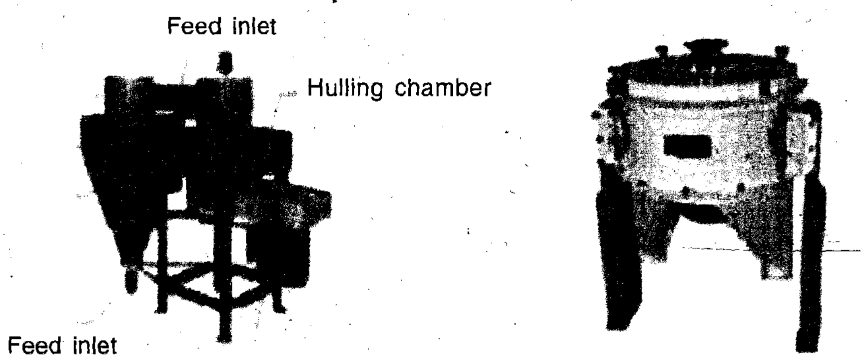

Fig. 4: Impact Huller

It consists of a high speed rotor, the speed of which is controlled by a vary speed drive. The rotor consists of impeller flights that are grooved to facilitate the alignment of oat grains in the direction of motion, permitting to strike the impact ring. The impact ring is mounted in the housing cover. Selection of impact ring material is based on its performance and life (durability). Rubber rings are preferred for high-hulling efficiency and less brokens they produce. As the oats kernels strike the impact ring, hulls are separated. The mixture of materials consisting of groats, hulls and unhulled kernels leave the outlet chute of the huller.

The stock coming from the outlet of the huller is then passed through an aspirator to remove the lighter hulls. Groats with a small percentage of unhulled oats is fed on to a table separator where the unhulled oats are separated. This stock is returned to a separate impact huller for converting into groats.

In some oat processing plants, hulling itself is done after the heat conditioning. Heating serves to make the hull more brittle and easy-to-dehull. Even if the drying is carried out following dehulling, some plant may exclude conditioning.

Conditioning and drying is an important part of the total process. This has far reaching implications on the product quality in terms of taste, storage and functionality. Here the groats are subjected to hydrothermal treatment in a steam conditioning unit. Groats are fed into a vertical steam conditioner. Steam is injected at several points and groats are exposed to steam evenly. The rate of application of steam is controlled to get the desirable inactivation of enzymes and partial gelatinization.

Steam conditioned groats are subjected to drying. This step is aimed at reducing the moisture added during steam conditioning and additionally, to maintain the temperature of oat kernels at the temperature range similar to that during steam conditioning for an extended period of time for inactivation of enzyme. But this period is regulated depending on the end product in mind.

Grading follows conditioning and drying operations. The groats may optionally be sent to a polisher if improving the colour of the product is important. Groats are size separated into small and large. Width graders are used for making separation between large and small groats. Small groats may be sent for steel cutting, whereas large groats are sent for flaking.

Production of oat flour and oat bran

Roller mills or even hammer mills may be used to grind different sized groats or finer products into one type of flour with all the bran and flour pulverized to a fine granulation. This may be referred to as whole oat flour. By being more selective in terms of grinding and sifting to remove the coarse material, oat flour is produced. The coarse material may be ground again to remove some more flour from it. Flour obtained in this gradual manner would be low as flour and the coarse material may be referred to as oat bran.

13.7.2 Milling of Barley

Use of barley for human food application has a long history. It was consumed by earlier civilizations as a staple, along with other cereals. Barley is still consumed as part of the staple diet in some countries; especially where consumption is in the form of whole grain is still in limited practice.

Barley is used worldwide for brewing, animal feed and human food. In the last century, barley has been used less for food than wheat because of lesser palatability, baking quality and milling characteristics. From the nutritional point of view, barley is equal to or better than wheat. Barley is eaten as popped barely, barley flakes, sprouts, barley starch and as sweeteners, barley malt flour supplements, malted milk, infant food syrups, barley tea or coffee substitute and rice extender.

Barley hulls are removed by shelling. Following the removal of hulls, it is pearled and may be cut and pearled again. Pearled barley may also be flaked; also it may be further reduced in size to form granular products of varying degrees of particle sizes to meet end product specifications.

The very first step before beginning the processing of barley is the consideration of quality criteria of the raw material, as is true with other grains. Pearling properties, test weight, moisture content, broken grains, materials other than grains (foreign matter), damaged and discoloured grains, uniformity of the stock, quality attributes desired for secondary processing.

Cleaning: The cleaning process for barley is dependent on how many types of impurities it contains. Cleaning begins with a magnet followed by a separator. The separator removes larger, smaller and lighter foreign materials using screens and aspiration methods. Barley is then directed to a destoner that removes stones and other heavy material as the same size of barley. Besides affecting the quality and being injurious if consumed, these are also particularly damaging to the pearlers that impart friction as a mode of its operation. If barley is very dirty with a lot of surface chaff, husks and seeds that are shorter, such as cockle and longer, such as sticks, oat and wild oats, then the cleaning section is equipped with other cleaning units. A battery of indented cylinders or disk separators is used for removal of short and long seeds that have different length,

Tempering or Conditioning: Barley is generally processed without addition of any water because it is naturally soft. But, there are certain varieties that are extremely hard and very low in moisture. It may be impossible to mill these varieties without addition of water. Under these conditions, barley may be subjected to a light pearling action before conditioning.

Barley pearler: The principle equipment used in milling of barley is the barley pearler. A barley huller-pearler essentially involves removal of the hulls by abrasion and friction between a grinding medium and a screen jacket. The grinding medium consists of several stone (emery) rings attached to a central shaft that runs at high speed. The intensity of such action can be controlled through four segmented outlet

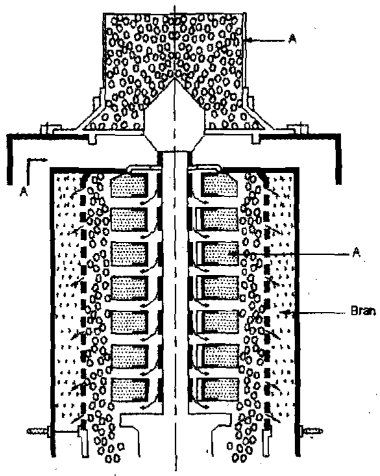

Fig. 5: Barley Pearler

slides controlled by micrometer screws from outside to regulate the residence time of material and thus degree of hulling and pearling can be controlled.

Operation of this machine involves feeding barley from the top. As the barley descends, filling the space between the emery rings and the perforated screen jacket surrounding the rings, it is subjected to friction among the kernels, abrasive stones and the screen. This friction and abrasion loosens, and ultimately detaches the hulls. This action creates a lot of heat and to cool the grains and blow out the hulls from the milling chamber air is allowed to enter through the rotor. This suction air with hulls is carried over to a cyclone or filter (dust collector). Degree of hulling/pearling can be controlled while the machine is in operation. Though a vertical type pearler is shown in figure 5 horizontal versions are also available.

In most situations, milling of barley primarily involves varying degrees of pearling action with or without in-between cutting followed by grading on screens to provide various grades of pearled barley. At times, the final pearling stage allows the product to be pearled to almost a round-shaped finished, pearled barley. This may also be rolled as well as the pearled and cut barley.

In some parts of the world, hulled barley would serve as the raw material for the milling section. In these roller type mills, pearled barley is subjected to size reduction and refining to suit various products to suit market requirements. Here, grinding and sifting of pearled barley may be carried out in a series of rollers and sifter sections.

13.7.3 Milling of Sorghum

The most highly refined sorghum products are produced by abrasive removal of the pericarp followed by degermination and physical separation and/or classification of dry milled fractions. Most of the traditional African and Indian foods are produced from decorticated sorghum which is milled into flour. Industrial decortication involves the use of mills with abrasive disks or carborundum stones. Whole sorghum flour can be produced by the use of stone, hammer, pin or roller mills.

Milling of coarse cereals and millets generally refer to decortication or debranning of grains to obtain pearled or decorticated grains and also to size reduction to produce semolina, grits and flour. Pearled or milled millets also possess better nutritive value and consumer acceptability.

A sound, dry uniform grain, uninfected by moulds and insects, of a defined variety and quality is the prerequisite for obtaining high quality products by milling. The grain contains impurities, such as broken kernels, other seeds, glumes, sticks, chaff, dirt and stones, which must be removed by sieving, aspiration and destoning.

A reasonably hard seed is important milling sorghum and millets; it is possible to upgrade a mixed seed lot on a density gradient table to concentrate the hard grains. As with wheat, it is often advantageous to condition sorghum and millets by adding water, mixing the mass thoroughly, followed by a resting period (tempering), before milling. Conditioning toughens the outer bran parts of the seed and makes them less prone to fine disintegration during milling, facilitating separation of the coarse bran particles form the endosperm, which due to its crystalline nature is more finely ground.

The storage proteins in grain sorghum are highly cross-linked and hydrophobic, which affect water absorption, processing conditions and digestibility in the milled sorghum flour. These problems are further exaggerated in high-tannin varieties containing polyphenols, which in large quantities are toxic and impair digestibility. It may be recalled here that, the pericarp of sorghum consists of three sub layers viz. pericarp, mesocarp and endocarp. The latter layer is important in decortication because it can take up moisture and it is here that breakage points are induced.

Generally, the most simple sorghum grains to mill by both traditional techniques or by machinery, are the ones with a pearly white appearance having a thin pericarp or with a starchy mesocarp, the latter giving a white chalky appearance. The ideal seed for milling should also have a reasonably hard endosperm in order to get the cleanest separation of the botanical tissue components, including a high yield of endosperm in the final product.

Equipment for dry and semi-wet milling of sorghum and millets

In most of the developing countries, pestle and mortar, quern or a power driven abrasive disk or a plate mill is used for milling of sorghum. However, roller milling was also attempted.

Traditional Roller Milling: Principle of wheat milling is applied here. After toughening the bran layer by water conditioning, the seed is squeezed and abraded through the shearing forces of two corrugated metal rollers of slightly different speeds (first break). Next, the flattened, large seed particles are carefully scraped off to remove the exposed endosperm by passing through a great number of corrugated and smooth rollers. The flour is sifted away in each milling step, each contributing a small percent to the total flour yield. It is found that colour and speckiness of roller milled sorghum flour due to incomplete bran separation limits its usefulness. Therefore, traditional roller milling method is not advocated for milling of jowar because of high processing costs, low extraction rate and relatively poor quality of flour.

However, some improvement in colour is made by lowering extraction and proper tempering. Semi wet processing involves steeping at 60 to 70° C for a short time with a water addition of 20-27%. Semi wet processing with roller mills have great advantages with regard to product quality, especially in milling high-tannin sorghum, but extraction rates are lower than usually commercially acceptable in milling low-tannin sorghum and millets.

Since the structure of sorghum grains is different from that of wheat, an approach opposite to that of roller milling i.e., decortication is advocated. This means that the bran and germ are removed first and separated to get dehulled endosperm. This could be milled separately.

Decortication

In applying the decortication principle to sorghum and millets, rice and barley dehullers/decorticators and polishers are being used. Work done at CFTRI has shown that rice milling equipment could be effectively used for decortication. Engelberg huller did not give satisfactory results. It produced high breakage, especially in the case of soft grains.

Attrition Type Decorticator

The operating elements in this type of dehuller are several, such as cylinders, often in the form of sieves, which can be pressurized with tightly packed seeds fed by a screw. The pressure is regulated with a valve in the outlet featuring a counter weight. Another element is rotating metal discs with grinding elements, most often one stationary and one moving, tuned for coarse milling. The seeds are introduced in the centre and brought by centrifugal forces to the periphery where treated seeds are collected.

The palyi compact mill Fig: 6 combines both of these principles. The hulling action is provided by the two attrition plates, one stationary and one fixed, fitted with saw tooth blades. The distance between the plates is adjustable, providing variable ratios between coarse (partly decorticated seeds) and finer particles (bran + broken endosperm). After the partly decorticated grains leave the plates, further attrition rubbing occurs when they pass the narrow opening between the rotating drum, which is a prolongation of the outer rotating attrition plate, and the surrounding stationary cylindrical sieve, which is fixed in the outer casting. Fine particles pass through the cylindrical screen peripherally, and decorticated seeds emerge through the cross section. A cover plate with springs produces a counter pressure on the exiting decorticated seeds. The cover plate pressure can be regulated, which determines the degree of decortication together with the speed of the motor and quality of attrition surfaces.

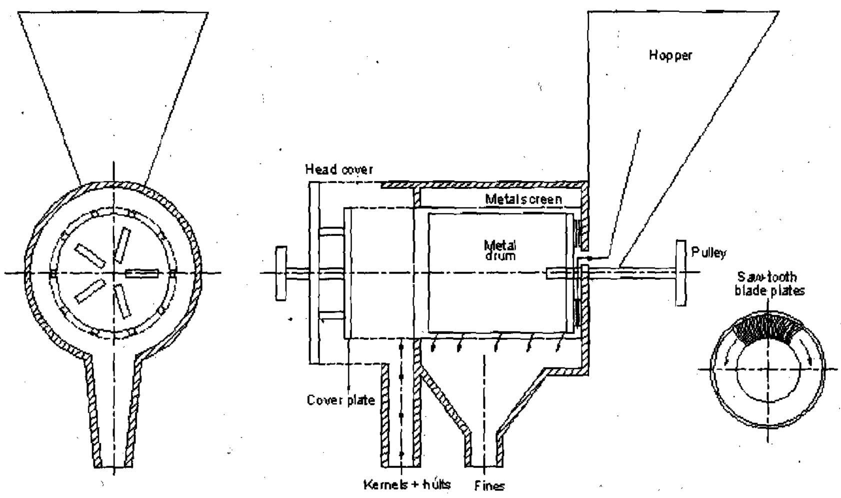

Fig. 6: Palyi Compact Mill

Pearling is found satisfactory in this mill but the extraction rates were found to be low. Some improvements have been carried out on the mill to improve the yield and for reducing the fibre content in the final product. A 'honey comb' disc was developed as a possible replacement for the saw tooth discs. A modified unit with a multiple combination of rotating discs with abrasive corrugated blades. High pressure air can pass through these hollow abrasive discs. Discs rotate at variable speed. The kernels are pressed against the abrasive discs and continuously debranned to the extent desired. (Fig 7)

In rice milling, the attrition principle is widely exploited in a range of milling machines. Cylindrical sieves pressurized by screws or internal rotors are also used to decorticate tempered sorghum. In the DVA sorghum decorticator (vertical type, as in figure below), the sorghum or millet kernels are conveyed by a screw into the decortication chamber, where a steel rotor rotates the grain mass towards the cylindrical screen. The pressure between the seeds during decortication can be

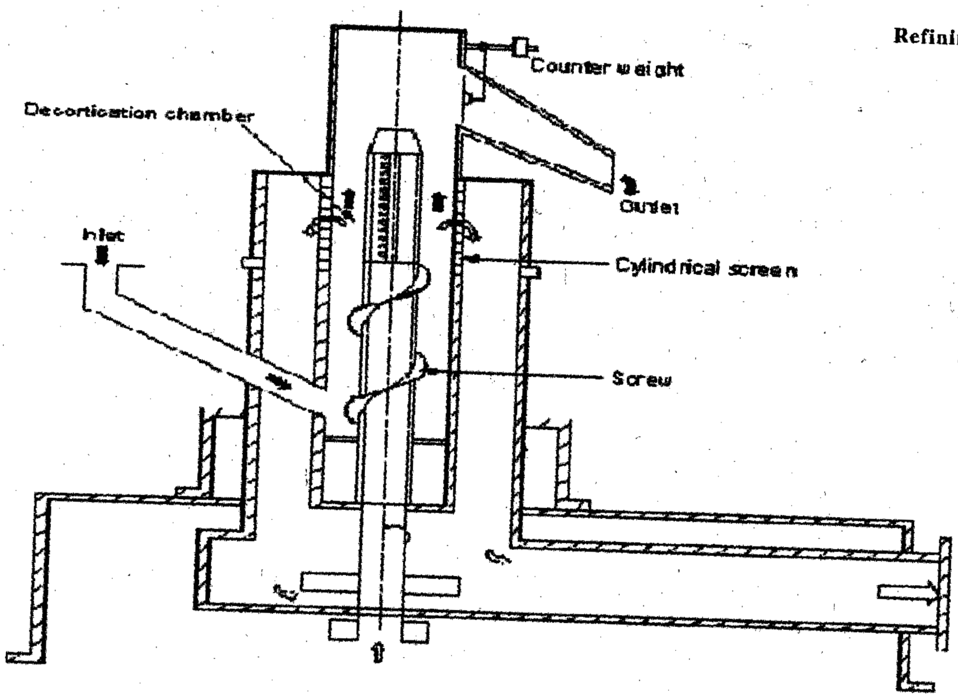

Fig. 7: DVAS Orghum Decorticator

controlled by the counter weight on the outlet. The hulls and the endosperm fragments from the cracked kernels are discharged through the screen by an air current at high pressure. This fraction- is sucked out from the bottom of the machine to a cyclone. (Fig 8)

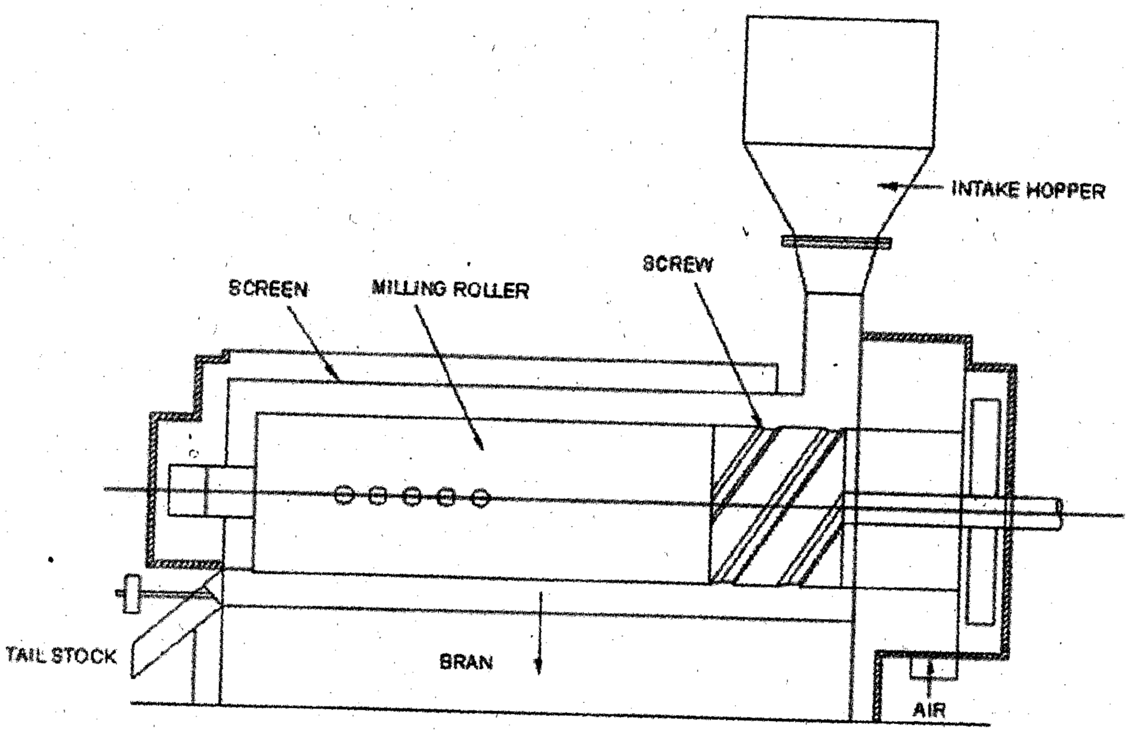

Fig. 8

Abrasion Type Decorticator

Abrasion milling utilizes carborundum or other abrasive surfaces mounted on a vertical or horizontal rotor in order to abrade, by friction grinding, the outer layers of the grain. Also here, there are several rice whiteners that utilize this principle either in the form of vertical core decortication or as in horizontal emery pearlers

(Fig: 9) where the new types often give the least breakage in sorghum milling. The vertical dehuller (Decomatic) was the prominent one of these types (Fig: 10)

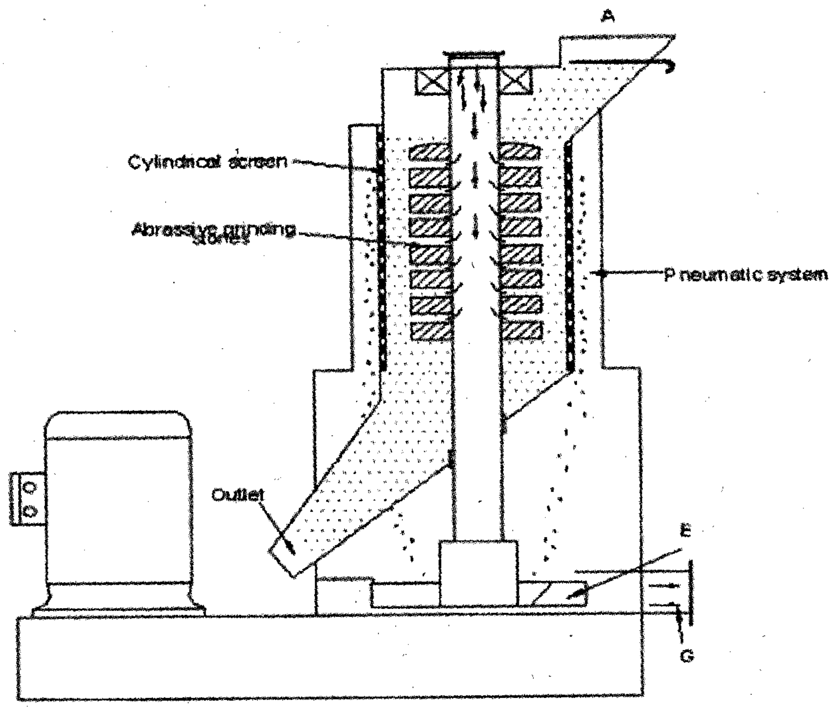

Fig. 9: Vertical Abrasive Polishing Machine

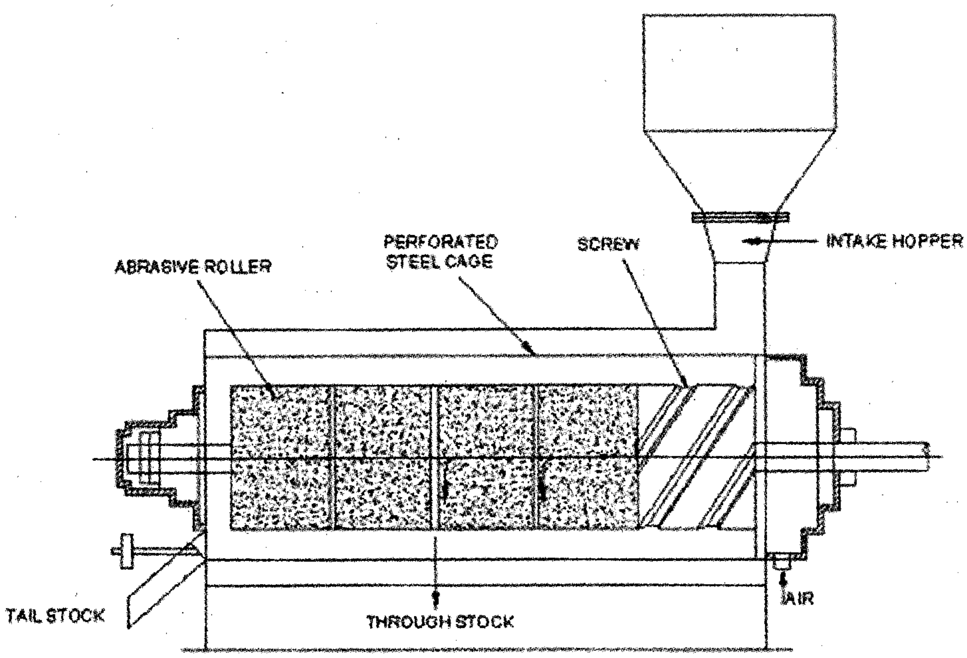

Fig. 10: Horizontal Abrasive Polisher

For semi-industrial and village use, the IDRC, Canada has developed a smaller horizontal type dehuller such as the PRL dehuller. This uses abrasive rotor fitted with resinoid discs, as shown in the (Fig: 11)

In a typical abrasion dehulling unit, the sorghum flows by gravity from above to the rotor equipped with segments of abrasive grinding stones, surrounded by a cylindrical screen. While the rotor runs, the kernels are abraded against the rough surface of the carborundum stones, against the peripheral screen, and against each

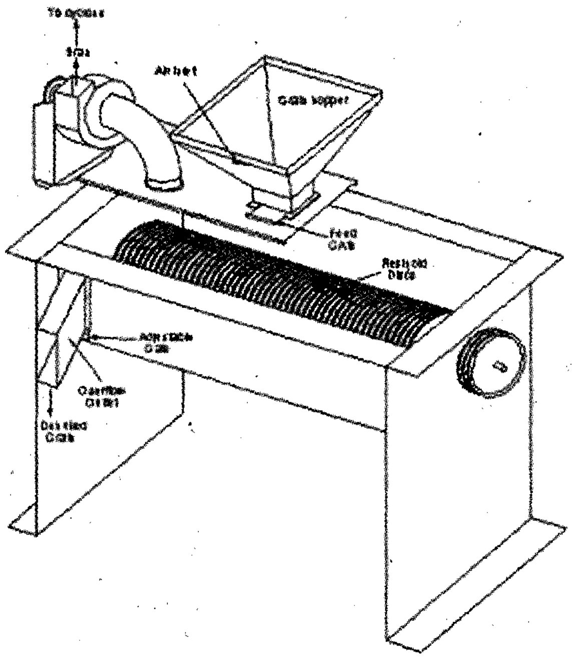

Fig. 11

other. Bran and endosperm particles are removed with a pneumatic system and collected in a cyclone. Degree of decortication can be regulated by controlling the flow at the outlet of the machine. Thus the time during which the kernels stay in the polisher can be regulated. Cracking of seeds should be avoided in order not to lose endosperm to the bran fraction.

A few small capacity decorticating units based on this principle have also come to the market.

The main difference between the attrition and abrasion decorticators is that bran and embryos in the first type of the machine mainly come out as more or less coarse bran flour, whereas the abrasion hullers produce by carborundum friction, much more homogeneous fine bran flour, also containing the embryos milled down. While in attrition decortication it is highly recommended to condition the seeds by water treatment prior to milling, this is often not feasible in abrasion milling.

Plate (Disk) Mills

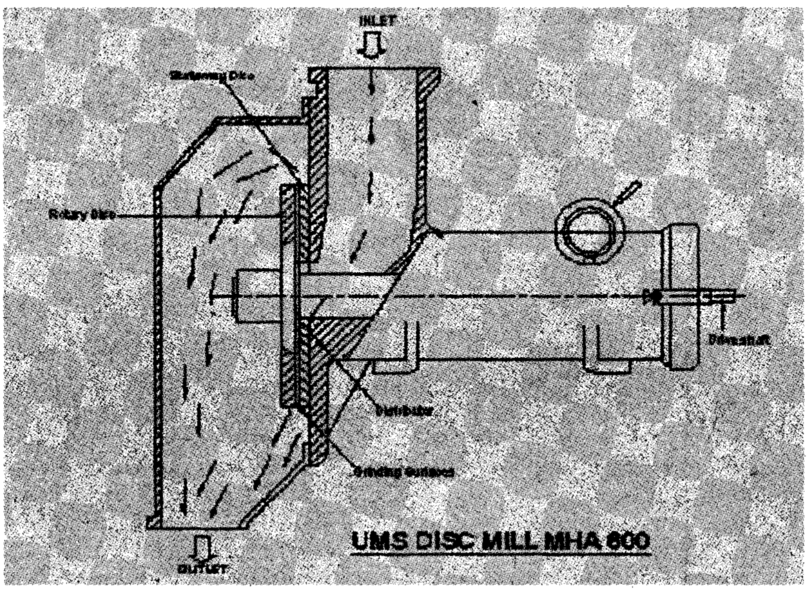

Fig. 12

The above-mentioned plate mill techniques can give reasonable results with carefully conditioned sorghum grain with the plates set (Fig: 12) rather close (e.g., 0.5 mm). After sieving in one step, coarse bran with a fine color and of fair quality can be obtained. Milling surface of the disk mill was also further developed from saw blades to radial corrugated milling surfaces made of hard metal.

Table 1:
Comparative Performance of Different Polishers for Pearling Sorghum

Type of polisher	Head Grains %	Big Brokens	Small Brokens	Total Yield %	Bran %
Horizontal Abrasive polisher	81.7	0.8	5.6	88.1	11.4
Vertical Abrasive polisher	54.9	27.4	0.8	83.1	16.2
Lab. McGill	57.3	10.5	16.6	84.4	14.3

Wet Milling of Sorghum

Wet milling of sorghum greatly resembles maize wet milling. The elaborate sorghum wet milling process is outlined in Fig: 13.

After the steeping process, the solids from the steep water are recovered in vacuum evaporators. They are then dried and mixed with sorghum gluten and sold as sorghum gluten meal, feed comparable to corresponding maize-wet milling product. The softened steeped seeds are gently milled in degerminator mills in water slurry to loosen germ, starch, gluten and fibers but keep them as intact as possible. Sorghum germ which is much smaller and more difficult to separate in whole form, than maize germ, is separated from the starch milk together with the gluten by overflow in liquid cyclones. Purified germ is dried and oil is pressed out, whereas the resulting protein is blended into the sorghum gluten meal. The starchy slurry from the germ separators is further milled at high speed in an impact mil and the fibers are removed by washing screens and joined to the feed fraction. Finally, the purified starch 'milk' is separated from gluten impurities in continuous starch centrifuges. After removing most of the water on starch filters, the wet starch is air dried at a sufficiently low temperature to avoid gelatinization. Pure, finished starch may be further processed into dextrins or into glucose.

13.7.4 Milling of Pearl millet

Among millets, pearl millet is known to contain a higher protein content and better amino acid balance than sorghum. Pearl millet is the cereal grain that most rapidly develops off-odors and off-flavors after milling. The reasons for the rapid deterioration are: high lipid content, higher amounts of unsaturated fatty acids, insufficient naturally occurring anti-oxidants and high enzymatic-hydrolytic activity. Whole pearl millet flour becomes rancid within 6 to 10 days of storage and inedible after 11-14 days.

Milling of pearl millet refers to decortication or debranning of grains to obtain pearled grains and also to size reduction to produce semolina, grits and flour. Traditional method of hand pounding is still practiced in some parts, wherein the grain is moistened and hand pounded. Although moistening helps in easy removal

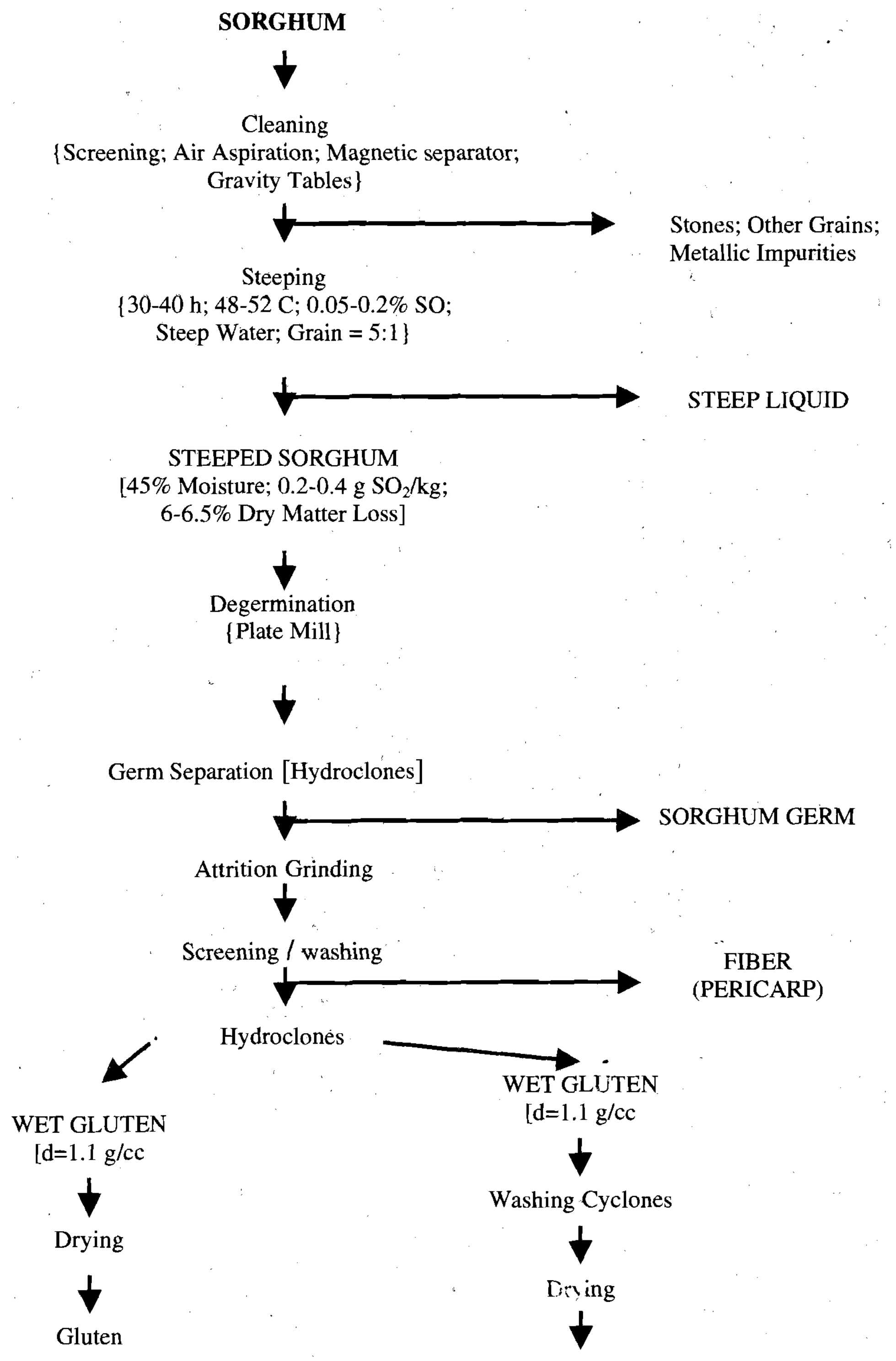

Fig. 13: Flow diagram for wet milling of sorghum

of bran, it causes breakage of endosperm and affects the keeping quality. Mechanization of milling to obtain pearled grains as well as grits and flour has been done with rice and wheat milling equipment. Abrasive type pearlers are found to be more effective for pearling than the attrition types. Work done at CFTRI has indicated that incipient moistening, tempering and milling in rice processing machinery can give good quality pearled grains. Food products prepared from the pearled millet flour possess better consumer acceptability that the whole meal flour.

SOTRAMIL process developed in Niger, involves grading of grains, followed by dehusking and decortication successively in horizontal mill stone and pulverizing in attrition mills. The extraction rate was 65 to 75% for an average particle size of

40 microns. The refined flour obtained in SOTRAMIL contains significantly less cellulose and lignin and slightly less lysine than whole grain.

The French SEPIAL process is another method that has been used to deglume and dehusk pearl millet, wherein the grain is superficially wetted and the moistened pericarp is detached by friction between the grains in an abrasive mill. The husked grains are decorticated by vigorous rubbing and brushing. The decorticated grain yield is found to be about 80%.

Studies on roller milling of pearl millet generally have not given good results and therefore, the method of decortication is recommended.

13.7.5 Milling of Ragi – finger millet

All cereals except finger millet and teff are poor sources of dietary calcium. Among the millets, finger millet has the coloured seed coat firmly attached with the softer endosperm. Attempts to debran the seeds and obtain the endosperm intact, either by chemical or mechanical process were not successful. Hence, the general method followed for milling finger millet involves grinding the endosperm to flour and separating a portion of the bran by sieving. Studies done at CFTRI indicate that moistening the seeds with about 5% water (w/w), tempering for about 30 minutes, followed by grinding and sieving helps in separating a major portion of the bran. Hammer mill, plate mill or even roller mill could be used for grinding conditioned ragi.

Recently, a pretreatment method has been developed at CFTRI to harden the otherwise soft endosperm of ragi. This can be conditioned and milled to get decorticated ragi in whole grain form.

Milling of other small millets

As described earlier, most of the small millets resemble paddy caryopsis in their morphology. Therefore, their milling involves dehusking, debranning and pulverization. Commercially it has been found that cone polishers are used for dehusking and debranning small millets like foxtail, little, kodo etc. Even the plate mill, with proper setting can also be used for dehusking these grains.

13.8 SIGNIFICANCE OF CRUDE FIBRE AND ASH CONTENT IN REFINING

To prepare a white, bright product, perceived by the consumers generally as the symbol of purity and wholesomeness, decortication plays a vital role. The mineral (ash) content of flour has been considered an important measure of the flour quality. Mineral content of flour *per se* may not always be related to functional quality, but it definitely gives some indication of the degree of refinement in processing.

As we already know from the previous lessons, crude fibre and hence ash as well as minerals is concentrated in areas adjacent to the bran coat and in bran itself. Flour products which contain higher levels of ash are darker in color and may be assumed to contain greater quantities of fine bran particles or of that portion of the endosperm adjacent to bran. Unfortunately, some grain varieties have a high percentage of ash in endosperm itself. Then refining will not be able to reduce the ash content and hence the colour of the flour to the desired level. Therefore, selection of the right quality of raw material assumes importance.

The ash test serves as an indirect measurement of the amount of bran present. Higher the ash content more is the bran in the flour. Use of ash as a marker is based on the fact that bran particles contain higher ash than endosperm. Aleurone layer of bran is the richest when it comes to ash.

Coarse grains may be decorticated to remove 8 to 30% of the grain. Decorticated grains or pearled kernels therefore have reduced levels of fiber, ash and fat. Higher the degree of decortication, greater would be the reduction in the crude fibre and ash content of the pearled grains and could be used as markers for the quality. Higher the degree of decortication, lesser would be product yield. Higher extraction and higher yield means higher ash and fibre and dark colour of the flour. An optimum balance has to be struck between the product yield (extraction) and the fibre, ash, fat and colour of the resultant flour.

Effect of decortication of these parameters can be seen from Table 2.

Table 2: Effect of decortication on the crude fibre and ash content of some coarse grains/milled products

Grain	Condition	Crude fibre	Total Ash
Sorghum	Native	1.8	1.7
	Polished (3.7%*)	1.0	1.5
	Polished (7.0%)	0.8	1.3
	Polished (9.5%)	0.7	1.1
	Big brokens	0.8	1.2
	Small brokens	0.8	1.2
	Bran – I pass	11.9	5.7
	Bran –II pass	6.4	5.2
	Bran – III pass	4.8	4.8
	Husk	8.6	7.2

*Figures in parentheses indicate degree of polish

Grain	Condition	Crude fibre	Total Ash
Pearl Millet	Native	3.0	2.3
	Polished (8%)	2.0	1.2
Maize	Native	3.1	NA
	Debranned	1.6	NA
Kodo	Native	11.3	5.6
	Debranned	0.4	4.0

Though the fibre and ash contents reduce appreciably upon milling, their nutritional quality may not be affected significantly. However, the product making quality of the flour and organoleptic quality of the products prepared from the resultant flour would be improved substantially. Refining of millets therefore, should be done judiciously not to lose the nutrients and at the same time improve the quality of the resultant flour.

Check Your Progress

Note: a) Use the space given below for your answers.

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

1. Explain the need for refining coarse cereals.

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2. Describe the traditional methods of milling coarse grains, with a suitable flow chart.

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3. How coarse grains can be refined? Explain the concept of refining.

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4. With a neat sketch, explain the working of a barley pearler.

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5. Explain the process of oat milling with a simplified block diagram.

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6. How and why is oat milling different from the milling of other coarse grains?

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7. Describe an attrition type decorticator use in the decortication of sorghum.

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8. Why roller milling is not generally employed for milling sorghum?

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9 Explain the significance of crude fibre and ash contents the process of decortication.

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13.9 LET US SUM UP

Maize, sorghum, oats, barley and small millets form the important coarse and minor cereals. For food uses, coarse cereals and millets are generally pulverized in attrition mills and a small portion of the bran is sieved off. Fibrous bran present in the whole meal flour results in coarseness which affects flour/dough quality, cooking quality and also the digestibility. Fat content of the resultant flour will also be high due to admixture of pulverized oil-rich germ, limiting the shelf life of flours. In essence, we can say that palatability and shelf life are the two major requirements of products obtained from these grains. In order to refine them and reduce the harmful effects of antinutritional factors, also to improve the flour quality and shelf life, coarse cereals and millets are subjected to decortication/ refining.

In order to get the desired refined flours, it is necessary to remove the bran layers and/or germ partially, if not completely. Thus refining of coarse grains includes partial or complete debranning and degerming. Thus, decortication is the process of partial/complete removal of outer layers of the grains and germ. Therefore, decorticated or pearled kernels would have reduced levels of fiber, ash and fat.

It is often advantageous to condition them by adding water, mixing the mass thoroughly, followed by a resting period (tempering), before milling. Conditioning toughens the outer bran parts and the bran is rendered lather leathery. This makes it less prone to fine disintegration during milling, facilitating separation of the coarse bran particles from the endosperm, which due to its nature is more finely ground. Coarse bran can either be sieved off or aspirated.

The principles and milling systems followed for coarse grains include: Rice milling machinery, Roller milling systems, Attrition type mills, Abrasive type dehullers or Combination of two or more of these systems followed by grinders. Some special milling systems have been developed for the major coarse cereals. Increased decortication causes increased losses of fiber, fat and ash. Higher the degree of decortication, lesser would be product yield. Higher extraction and higher yield means higher ash and fibre and darker colour of the flour. An optimum balance has to be struck between the product yield (extraction) and the fibre, ash, fat and colour of the resultant flour. Similarly, loss of nutrients during refining is also important and milling should therefore be done judiciously.

13.10 KEY WORDS

Coarse Cereals : Maize, Sorgum, oats, rye are categorized as coarse cereals and they play an important part in human diet.

Milling of coarse cereals	:	Simplest way of processing/milling of coarse cereals is to grind the whole grain, sieve away the coarse bran particles and get about 90-95 % extraction of the product.
Decorticated grain	:	Grain from which bran has been removed.
Dehulling	:	The process by which the inedible hulls are removed from the grain such as oats.
Crude fibre	:	Portion of grain concentrated in the brain layer.
Refining of coarse cereals	:	It is the process by which palatability and shelf life of products is increased.

13.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

1. Cereal grains are a rich source of fiber. If the whole grain is ground, fibrous bran results in coarseness of the resultant flour. Coarse bran affects flour/dough quality, cooking quality and also the digestibility. Also, germ present in the grains is rich in lipids. If the whole grain flour is obtained, germ also gets pulverized and the fat content of the flour will be high. This results in poor shelf life of the flours.

   Coarse cereals generally have a coarse, fibrous husk/bran resistant to enzymatic digestion. The outer most layers of bran/glumes are fibrous, tough and irritating to the tongue. They also resist water permeability making cooking very difficult. Bran from most of the coarse cereals contains coloured pigments and also some anti nutritional factors. These grains also have strong characteristic odour which may not be liked by all.

   In order to improve palatability and shelf life of products and also to reduce the ill effects of anti-nutritional factors, coarse cereals are to be decorticated/ refined.

2. Coarse grains are invariably subjected to grinding for conversion to flour. Traditional method of pounding the grains using mortar and a pestle is still practiced in some parts. The other simplest way of milling coarse grains is to grind the whole grain in the stone quern, manually. In both the cases, resultant flour or semolina is sieved and overtails are returned for further size reduction.

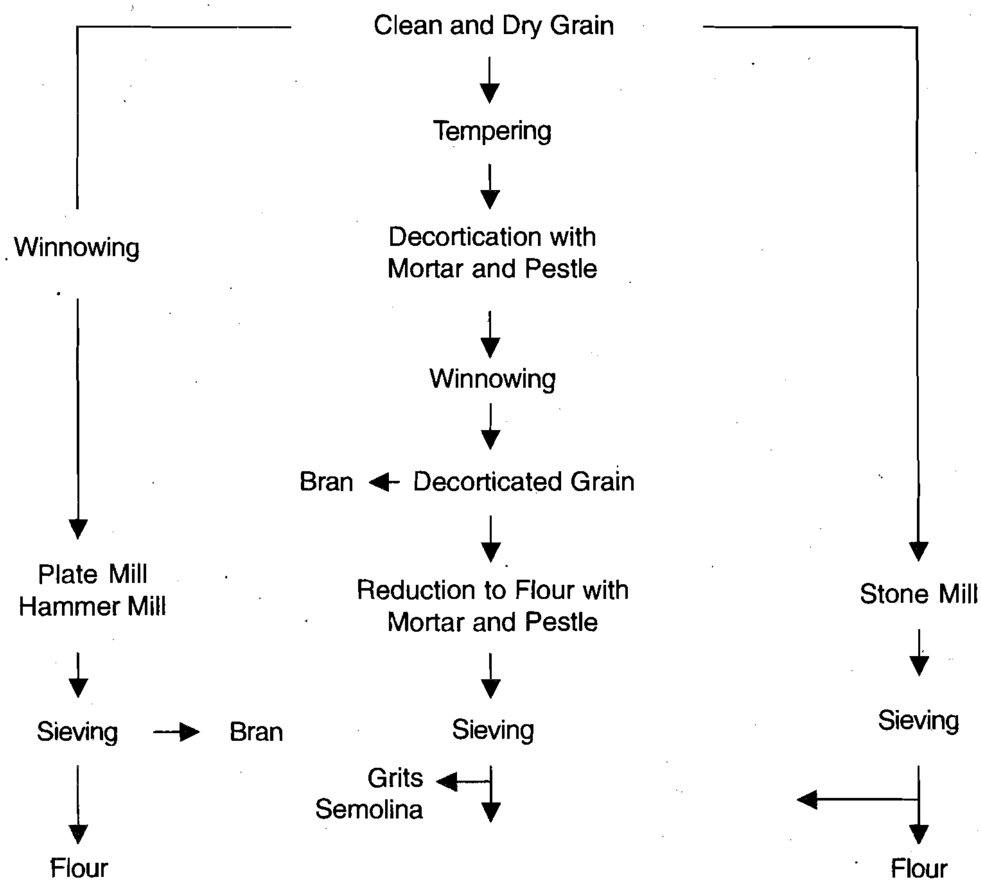
   In the machine driven units viz., stone mill (with carborundum disks), plate mills (chakkis) or hammer mills, mill parameters are adjusted to get the required particle size of flour/grits. More commonly, whole grain is dry ground in these mills to grits, semolina or flour and the product is sieved to discard the bran.

   The other method in the traditional milling is to moisten the grain just prior to pounding. As the moisture does not penetrate deep into the endosperm, this facilitates easy peeling of the pericarp from the endosperm. During the process of pounding, additional water might be added if necessary. The pounded grains are sun dried for a few minutes and winnowed to separate the bran. These grains are washed in excess water and sun dried to obtain the desirable product. Here, although moistening facilitates easy removal of bran, it causes breakage of endosperm and affects keeping quality.

   In general, traditionally milled products retain relatively more nutrients. Obviously, the manual methods are laborious and the capacities are too low.

Quality of the resultant product is also not very good because of the high moisture content of the flour and mixing of the ground bran. However, flour products from mechanical methods are found to have better preference and they have improved shelf life.

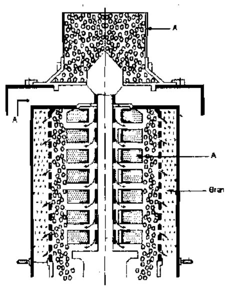
Traditional methods of milling coarse grains can be summarized in the following flow diagram:



3. Decortication or refining is the process of partial/complete removal of outer layers of the grains and germ. It is necessary to remove the bran layers and/or germ partially, if not completely to get refined flours.

   Incipient moist conditioning followed by pearling or grinding and sieving has been found to be practical to obtain low fiber grits and flour. It is often advantageous to condition coarse grains by adding water, mixing the mass thoroughly, followed by a resting period (tempering), before milling. Conditioning toughens the outer bran parts and the bran is rendered rather leathery. This makes it less prone to fine disintegration during milling, facilitating separation of the coarse bran particles from the endosperm, which due to its nature is more finely ground. Coarse bran can either be sieved off or aspirated.

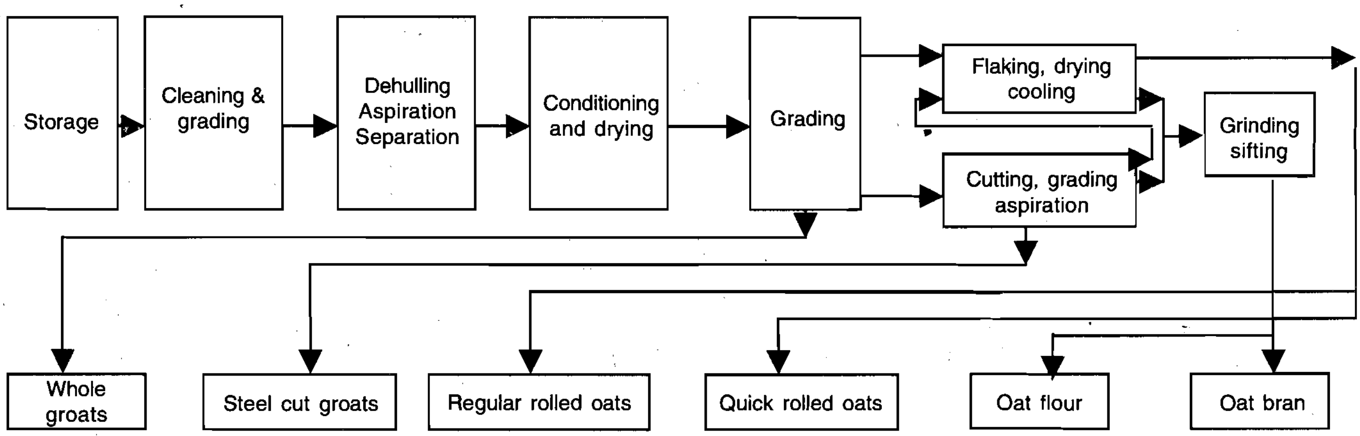
4. A barley pearler uses the principle of abrasion and friction to remove hulls from grains fed into the interstitial space between the grinding stone and the screen jacket. The grinding medium consists of several stone (emery) rings attached to a central shaft that runs at high speed. The intensity of pearling action can be controlled through four segmented outlet slide gates. By controlling their position, residence time of stock inside the milling chamber can be regulated and thus degree of pearling can be controlled.



Barley is fed into the unit from the top. As the barley descends filling the space between the rotating emery rings and the perforated screen jacket, grains are subjected to friction among the kernels, abrasive stones and the screen. This friction and abrasion loosens, and detaches the hulls. This action creates a lot of heat and to cool the grains and blow out the hulls from the milling chamber air is allowed to enter through the rotor. This suction air with hulls is carried over to a cyclone or filter (dust collector). Degree of hulling/pearling can be controlled while the machine is in operation.

5. Milling process of oats begins with the cleaning. Cleaning is followed by grading before dehulling. Dehulling operation removes the hulls. Oat kernels without the hulls (groats) are sent for conditioning and drying. Conditioned groats are then graded and subsequently sent for cutting or flaking. Some of the material may also be ground and sifted for oat flour and bran production.

Simplified block diagram of oat milling:



Cleaning of oats is generally elaborate. In old, traditional mills grading may be just limited to sifters. In modern mills, a grain separator with air classifier is used to remove larger, finer and lighter foreign material from oats. This stock is destoned and subjected to size separation. Then, it is passed through a gravity separator to separate impurities that have different specific gravity and a paddy separator to remove materials of equal size, shape and specific gravity, but with a different surface texture. This helps to optimize dehulling. The next cleaning machine could be a clipping unit which would separate the double oats, and clip off the ends of oat kernels.

Primary aim of the hulling operation is to remove inedible hulls. In old mills, hulling was done using stone hullers. As this used to demand lower moisture content of oats, kiln drying was being practiced. Modern mills have adapted impact dehullers wherein oats can be dehulled in their normal moisture range (12-14%) and thus kiln drying is not required. However, drying before impact hulling improves hullability as this makes the hull brittle.

Mixture of groats, hulls and unhulled kernels produced by the dehulling action is aspirated to remove the hulls. Mixture of groats and unhulled oats is fed to a table separator to separate unhulled oats. Unhulled oat grains are sent back for dehulling.

Conditioning and drying is an important part of the oat milling process as this has implications on product quality. Groats are subjected to hydrothermal treatment in a steam conditioning unit. Steam application is regulated to get the desirable enzyme inactivation and partial gelatinization.

Steam conditioned groats are then subjected for drying. Apart from reducing the moisture added during steaming, this can be used as an extended period of conditioning for inactivation of enzymes. This period is regulated depending on the end product being produced.

Grading follows conditioning and drying operations. The groats may be optionally sent to a polisher if improving the colour of the product is important. Groats are size separated into small and large. Small groats may be sent for steel cutting, whereas large groats are sent for flaking. Roller mills or even hammer mills may be used to grind groats of different sizes. This may be referred to as whole oat flour. If the flour is sieved to remove the coarse material, oat flour is produced. Coarse material is referred to as oat bran.

6. Milling process of oats is very different from the rest of the cereal grains. This is primarily because of the following reasons:

   - The hulls strongly adhere to the kernel or groat
   - Oat kernels have very high fat content and should to be stabilized through heat treatment for prevention of rancidity
   - The form in which it is consumed is also quite different from the other grains

7. Attrition principle is widely exploited in a range of milling machines. Cylindrical sieves pressurized by screws or internal rotors are also used to decorticate tempered sorghum. In the DVA sorghum decorticator (vertical type, as in figure below), the sorghum or millet kernels are conveyed by a screw into the decortication chamber, where a steel rotor rotates the grain mass towards the cylindrical screen. The pressure between the seeds during decortication can be controlled by the counter weight on the outlet. The hulls and the endosperm fragments from the cracked kernels are discharged through the screen by an air current at high pressure. This fraction- is sucked out from the bottom of the machine to a cyclone.

   The operating elements in this type of dehuller are several, such as cylinders, often in the form of sieves, which can be pressurized with tightly packed seeds fed by a screw. The pressure is regulated with a valve in the outlet featuring a counter weight. Another element is rotating metal discs with grinding elements, most often one stationary and one moving, tuned for coarse milling. The seeds are introduced in the centre and brought by centrifugal forces to the periphery where treated seeds are collected.

   The palyi compact mill (as in fig below) combines both of these principles. The hulling action is provided by the two attrition plates, one stationary and one fixed, fitted with saw tooth blades. The distance between the plates is adjustable, providing variable ratios between coarse (partly decorticated seeds) and finer particles (bran + broken endosperm). After the partly decorticated grains leave the plates, further attrition rubbing occurs when they pass the narrow opening between the rotating drum, which is a prolongation of the outer rotating attrition plate, and the surrounding stationary cylindrical sieve, which is fixed in the outer casting. Fine particles pass through the cylindrical screen peripherally, and decorticated seeds emerge through the cross section. A cover plate with springs produces a counter pressure on the exiting decorticated seeds. The cover plate pressure can be regulated, which determines the degree of decortication together with the speed of the motor and quality of attrition surfaces.

8. In the roller milling process, water conditioned grains are squeezed and abraded by the shearing forces of two corrugated metal rollers rotating in opposite [illegible] slightly different speeds. Then, these flattened, large grain particles

are scraped off to remove the exposed endosperm by passing through more number of corrugated as well as smooth rollers. The flour is sifted away in each milling step, each contributing a small percent to the total flour yield.

It is found that colour and speckiness of roller milled sorghum flour due to incomplete bran separation limits its usefulness. Since the structure of sorghum grains is different from that of wheat, an approach opposite to that of roller milling i.e., decortication is advocated. During this process, bran and germ are removed first and separated to get dehulled endosperm. Then these pearled grains are subjected to size reduction.

Also, the processing cost of roller milling of sorghum is generally high, extraction rates are lower and quality of flour will also be relatively poor. Therefore, traditional roller milling method is not advocated for milling of jowar.

9. Decortication plays a vital role in preparing a white, bright, product acceptable to consumers. Flour products which contain higher levels of crude fibre/ash are darker in color and contain greater quantities of bran. Crude fibre and minerals/ash are concentrated in areas adjacent to the bran coat and in bran itself. Aleurone layer of bran is the richest when it comes to ash.

   Higher the ash/crude fibre content more is the bran in the flour. Use of ash as a marker is based on the fact that bran particles contain higher ash than endosperm. This gives the indication of degree of refinement in processing. Decorticated grains or pearled kernels have reduced levels of fiber, ash and fat. Higher the degree of decortication, greater would be the reduction in the crude fibre and ash content. Therefore, the mineral (ash) content of flour can be considered an important measures/ markers of the flour quality.

   Higher the degree of decortication, lesser would be product yield. Higher extraction and higher yield means higher ash and fibre and dark colour of the flour. Upon milling, fibre and ash contents reduce appreciably and the product making quality of the flour and organoleptic quality of the products prepared from the resultant flour improves substantially. An optimum balance has to be struck between the product yield (extraction) and the fibre, ash, fat and colour of the resultant flour and here, the measures of crude fibre and ash can be very significant.

13.12 SOME USEFUL REFERENCES

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