
UNIT 6 MILLING

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6.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the principles and methods of milling;
- describe the various milling equipments, their efficiencies and relevant methods used for various products; and
- understand the importance of milling, their impact and utility and be able to decide the suitability of different machinery for various products.

6.1 INTRODUCTION

Milling is a general trade name, which normally means reduction of food material into various end products like meal, pulp, flour, splitted products etc. Milling includes cleaning, grading, separating, mixing, pearling, polishing, dehushing, size reduction etc. The meaning of the term milling varies with the commodity. For example, milling of wheat refers to a grinding operation to produce flour, whereas in rice industry, milling refers to overall operations in a rice mill i.e. cleaning, dehushng, paddy separation, bran removal and grading of milled rice. Milling also refers to extraction of juice, oil or separation of fibre etc.

Most of the agricultural products are in solid form which is generally difficult to handle, compared to liquid and gases. In processing, solids appear in many forms as large irregular pieces or finely divided powders. These particles may be hard and abrasive, soft, brittle, dusty or sticky and plastic. According to the forms of solids, means are to be found to manipulate them into end products and possibly to improve their handling and processing characteristics.

6.2 METHODS OF MILLING

The methods of milling are similar to those discussed in the previous unit on size reduction. However, in case of fruits and vegetables, milling may refer to the juice extraction, cutting for different purposes, etc. For oilseeds it is the

expression of oil by compression, solvent extraction etc. and for grains it will vary from one grain to another, for example rice milling would mean hulling, shelling, polishing etc. whereas for wheat it is simple grinding and separation into different fractions and for pulses the dehulling and splitting of the grains.

6.3 MILLING EQUIPMENT

6.3.1 Milling Equipment for Solid Foods

Size reduction of fibrous foods

Most fruits and vegetables fall into the general category of 'fibrous' foods. Fruits and vegetables have an inherently firmer texture and are cut at ambient or chill temperatures. There are five main types of size reduction equipment, classified in order of decreasing particle size, as follows.

1. Slicing equipment consists of rotating or reciprocating blades which cut the food as it passes beneath. In some designs food (Figure 6.1) is held against the blades by centrifugal force. In other (for slicing meats) the food is held on a carriage as it travels across the blade. Harder fruits such as apples are simultaneously sliced and de-cored as they are forced over stationary knives fitted inside a tube. In a similar design (the hydro cutter) foods are conveyed by water at high speed over fixed blades.

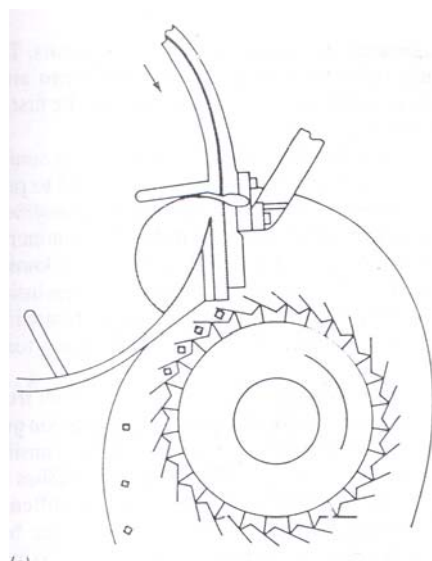


Figure 6.1: Slicing equipment

2. Dicing equipment is for vegetables, fruits and meats. The food is first sliced and then cut into strips by rotating blades. The strips are fed to a second set a rotating knives which operate at right angles to the first set and cut the strips into cubes (Figure 6.2).

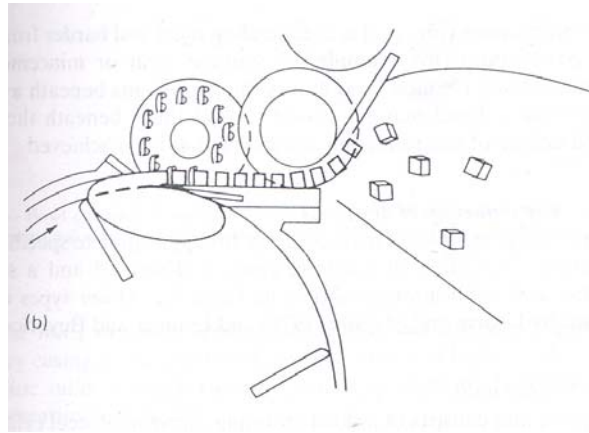


Figure 6.2: Dicing equipment

3. *Flaking equipment* for flaked nuts, fish or meat is similar to slicing equipment. Adjustment of the blade type and spacing is used to produce the flakes.
4. *Shredding equipment*. Typical equipment is a modified hammer mill in which knives are used instead of hammers to produce a flailing or cutting action. A second type of shredder is known as the *squirrel cage disintegrator*. Here two concentric cylindrical cages inside a casing are fitted with knife blades along their length. The two cages rotate in opposite directions and food is subjected to powerful shearing and cutting forces as it passes between them.
5. *Pulping equipment* is used for juice extraction from fruits or vegetables and for pureed and pulped meats. A combination of compression and shearing forces is used in each type of equipment. A rotary grape crusher consists of a cylindrical metal screen fitted internally with high-speed rotating brushes or paddles. Grapes are heated if necessary to soften the tissues, and pulp is forced through the perforations of the screen by the brushes. The size of the perforations determines the fineness of the pulp. Skins, stalks and seeds discarded from the end of the screen. Other types of pulper, including roller presses and screw presses are used for juice expression.

A *bowl chopper* (Figure 6.3) is used to chop meat and harder fruits and vegetables into a coarse pulp (for example for sausage meat or mincemeat preserve). A horizontal, slowly rotating bowl moves the ingredients beneath a set of high-speed rotating blades. Food may be passed several times beneath the knives until required degree of size reduction and mixing has been achieved.

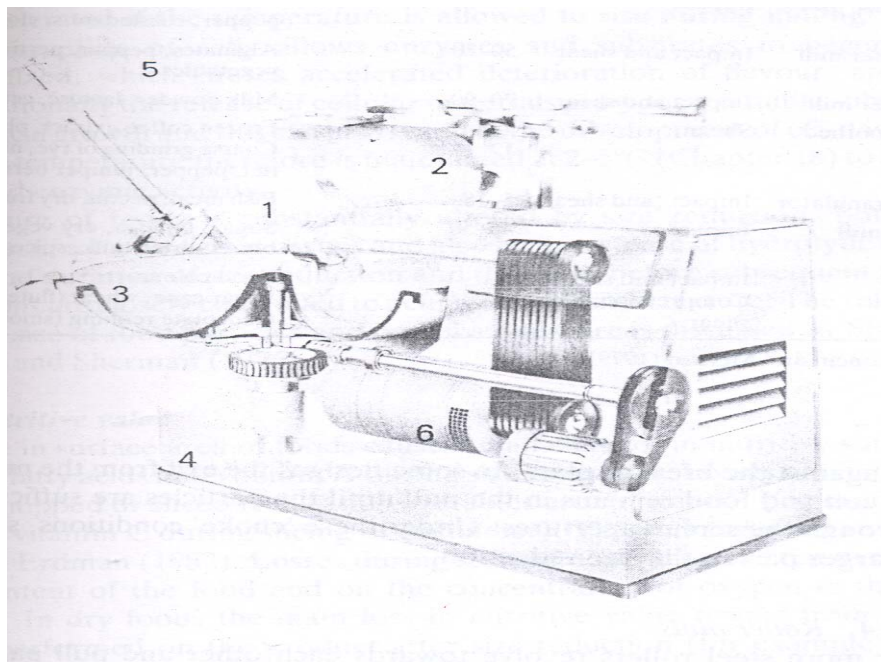


Figure 6.3: Bowl chopper: 1) Cutting blades, 2) Cover, 3) Rotating cutter bowl, 4) Casings; 5) Rotating unloader disc; 6) Main motor drive

Size reduction of dry foods

There are a large number of mills available for application to specific types of food.

Ball mills

This type of mill consists of a slowly rotating, horizontal steel cylinder which is half filled with steel balls 2.5-15cm in diameter. At low speeds or when small balls are used, shearing forces predominate. With larger balls or at higher speeds, impact forces become more important. A modification of the ball mill named the *rod mill* has rod instead of balls to overcome problems associated with the balls sticking in adhesive foods.

Disc mills

There are a large number of designs of disc mill. Each type employs shearing forces for fine grinding or shearing and impact forces for coarser grinding. For example,

1. single-disc mills in which food passes through an adjustable gap between a stationary casing and a grooved disc which rotates at high speed,
2. double-disc mills in which two discs rotate in opposite directions to produce greater shearing forces, and
3. pin-and-disc mills which have intermeshing pins fixed either to the single disc and casing or to double discs. (Figure 6.4)

These improve the effectiveness of milling by creating additional impact and shearing forces.

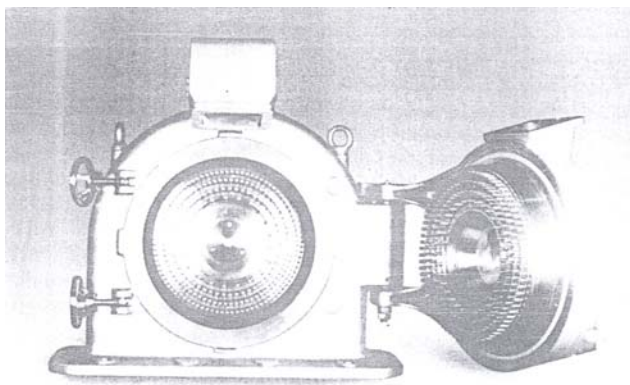


Figure 6.4: Pin and disc mill

Hammer mills

A horizontal cylindrical chamber is lined with a toughened steel breaker plate. A high-speed rotor inside the chamber is fitted with hammers along its length (Figure 6.5). In operation, food is disintegrated mainly by impact as the hammers drive it against the breaker plate. In some designs the exit from the mill is restricted by a screen and food remains in the mill until the particles are sufficiently small to pass through the screen apertures. Under these 'choke' conditions; shearing forces play a larger part in the size reduction.

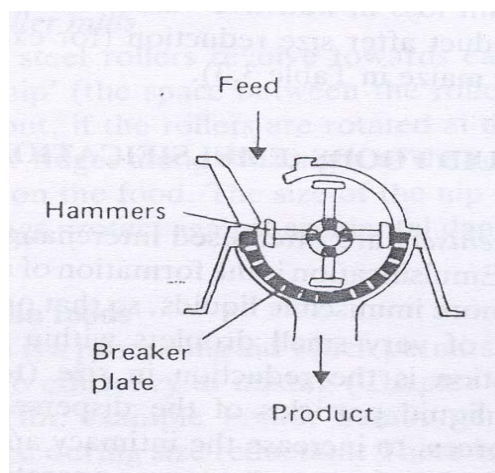


Figure 6.5: Hammer mill

Roller mills

Two or more steel rollers revolve towards each other and pull particles of food through the 'nip' (the space between the rollers) (Figure 6.6). The main force is compression but, if the rollers are rotated at different speeds, or if the rollers are fluted (shallow ridges along the length of the roller), there is an additional shearing force exerted on the food. The size of the nip is adjustable for different foods and overload springs protect against accidental damage from metal or stones.

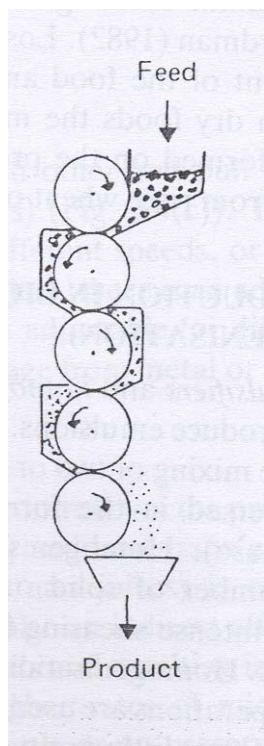


Figure 6.6: Roller mill

6.3.2 Milling Equipment for Liquid Foods (Emulsification and Homogenisation)

The terms emulsifiers and homogenisers are often used interchangeably for equipment used to produce emulsions. Emulsification is the formation of a stable emulsion by the intimate mixing of two or more immiscible liquids, so that one (the dispersed phase) is dispersed in the form of very small droplets within the second (the continuous phase). Homogenisation is the reduction in size (to 0.5-3 μ m) and increase in number of solid or liquid particles of the dispersed phase, by the application of intense shearing forces, to increase the intimacy and stability of the two substances. Homogenisation is therefore a more severe operation than emulsification. Both operations are used to change the functional properties or eating quality of foods. They have little or no effect on nutritional value or shelf life.

The four main types of homogenizer are as follows:

1. high-speed mixers;
2. pressure homogenisers;
3. colloid mills;
4. ultrasonic homogenisers.

High-speed mixers

Turbine or propeller-type high-speed mixers are used to pre-mix emulsions of low-viscosity liquids. They operate by shearing action on the food at the edges and tips of the blades.

Pressure homogenisers

These consist of a high-pressure pump, operating at 10,000-70,000kPa, which is fitted with a homogenizing valve on the discharge side. An example of one of the many different designs of valve is shown in Figure 6.7. When liquid is

pumped through the small, adjustable gap ($300\mu\text{m}$) between the valve and the valve seat, the high pressure results in a high liquid velocity (8400 ms^{-1}). There is then an almost instantaneous drop in velocity as the liquid emerges from the valve. These extreme conditions of turbulence produce powerful shearing force. The collapse of an air bubbles (termed *cavitation*) and impact forces created in some valves by placing a hard surface (a *breaker ring*) in the path of the liquid further reduce the globule size. In some foods (for example milk products) there may be inadequate distribution of the emulsifying agent over the newly formed surfaces, which causes fat globules to clump together. A second similar valve is then used to break up the clusters of globules. Pressure homogenisers are widely used before pasteurisation and ultrahigh-temperature sterilisation of milk, and in the production of salad creams, ice cream and some sauces.

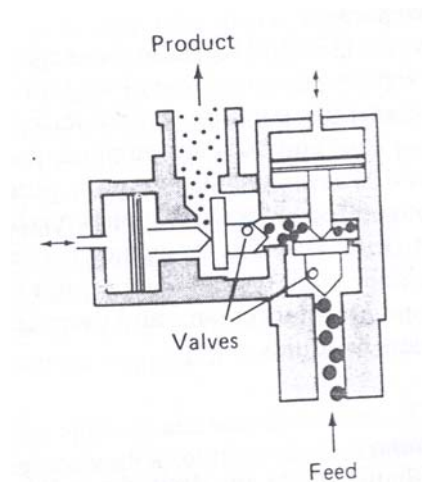


Figure 6.7: Hydraulic two-stage pressure homogenizing valve

Colloidal mills

These homogenisers are essentially disc mills. The small ($0.05\text{--}1.3\text{ mm}$) gap between a vertical disc which rotates at $3000\text{--}15000\text{ rev min}^{-1}$, and a similar-sized stationary disc creates high shearing forces. They are more effective than pressure homogenisers for high-viscosity liquids, but with intermediate-viscosity liquids they tend to produce larger droplet sizes than pressure homogenisers do. Numerous designs of disc, including flat, corrugated and conical shapes, are available for different applications. Modifications of this design include the use of two counter-rotating discs or intermeshing pegs on the surface of the discs to increase the shearing action. For highly viscous foods (for example peanut butter, meat or fish pastes) the discs may be mounted horizontally (the *paste mill*). The greater friction created in viscous foods may require these mills to be cooled by recirculating water.

Ultrasonic homogenisers

High-frequency sound waves ($18\text{--}30\text{ kHz}$) cause alternate cycles of compression and tension in low-viscosity liquids and cavitation of air bubbles, to form an emulsion with droplet sizes of $1\text{--}2\mu\text{m}$. In operation, the dispersed phase of an emulsion is added to the continuous phase and both are pumped through the homogenisers at pressures of $340\text{--}1400\text{ kPa}$. The ultrasonic energy is produced by a metal blade, which vibrates at its resonant frequency. Vibration is produced either electrically or by the liquid movement (Figure 6.8). The frequency is controlled by adjusting the clamping position of the blade. This

type of homogeniser is used for the production of salad creams, ice cream, synthetic creams and essential oil emulsions. It is also used for dispersing powders in liquids.

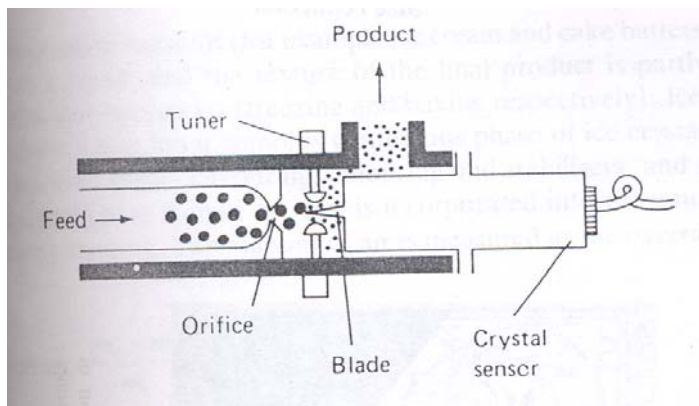


Figure 6.8: Ultrasonic homogenizer

6.4 EFFICIENCY OF MILLING

To achieve good results from any milling machine the followings should be given due care, (1) feed should be of proper size and feeding rate should be uniform, (2) hard or unbreakable material is not-allowed to enter the mill, (3) after grinding the product is removed as soon as possible, and (4) there should be some arrangement to remove the heat generated during milling operation.

Determination of power requirement for a particular grinding job is difficult. The exact amount of power requirement depends on type of material, moisture content of feed, material feed rate, type and condition of mill, product particle size requirement, nature of abrasive surface etc.

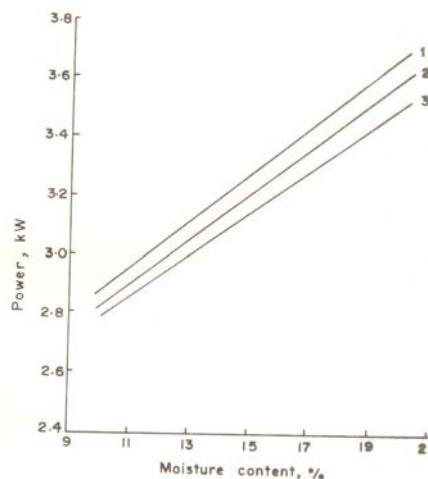


Figure 6.9: Effect of moisture content on power requirement: 1) 2800 rpm, 2) 2680 rpm, 3) 2560 rpm.

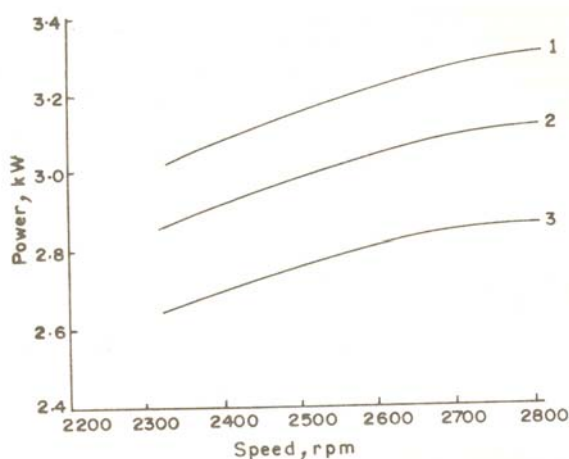


Figure 6.10: Effect of speed of operation on power requirement: 1) 17.9% moisture content, 2) 15% moisture content, 3) 11.8% moisture content.

Grains at higher moisture content are more difficult to grind than dry grains. The effect of moisture upon the power requirement for grinding of wheat with swinging hammer mill is shown in Figure 6.9. It was also found that fibrous materials require more power for grinding than non-fibrous material. At increased rotational speed the power requirement also increases (Figure 6.10).

Energy consumption: In size reduction of solids, bulk of the energy input is dissipated as heat energy. This energy raises the temperature of milled product, the mill and the air. Some of the energy is lost during vaporization of grain moisture. Comparatively small fraction of energy input is utilized for creation of new surfaces. During grinding of grains the temperature rise is observed to be 20°C or more in emery burr mills. This temperature rise may partially decompose some materials. Therefore, there should be some arrangement to remove this heat. In some abrasive mills provision is made to draw ambient air for cooling purposes.

6.5 METHODS OF SEPARATION

The unit operation of separation can involve separating a solid from a solid, as in the peeling of potatoes or the shelling of nuts; separating a solid from a liquid, as in the many types of filtration; or a liquid from a solid, as in pressing juice from a fruit. It might involve the separation of a liquid from a liquid, as in centrifuging oil from water, or removing a gas from a solid or a liquid, as in vacuum removal of air from canned food in vacuum exhausting.

One of the commonest forms of separating in the food industry is the hand sorting and grading of individual units as in the case of vegetables and fruit. However, because of the high cost of labour, mechanical and electronic sorting devices have been developed. Difference in colour can be detected with a photocell and off-colour products rejected. This can be done at enormous speeds with automatic rejection of discoloured or mouldy nuts or kernels of grain that flow past the photocell. In the case of peanuts to be made into peanut butter, each peanut individually passes through a light beam that activates a jet of air to blow the discoloured peanuts from the main stream when an off-colour changes the amount of reflected light. Light shining through eggs can detect blood spots and automatically reject such eggs. Automatic separation according to size is, easily accomplished by passing fruits or vegetables over different size screens, holes, or slits.

The skins of fruits and vegetables may be separated using a lye peeler (Figure 6.11). Peaches, apricots, and the like are passed through a heated lye solution. The lye or caustic softens the skin to where it can be easily slipped from the fruit by gentle action of mechanical fingers or by jets of water. Differences in the density of the fruit and skin can then be used to float away the removed skin.

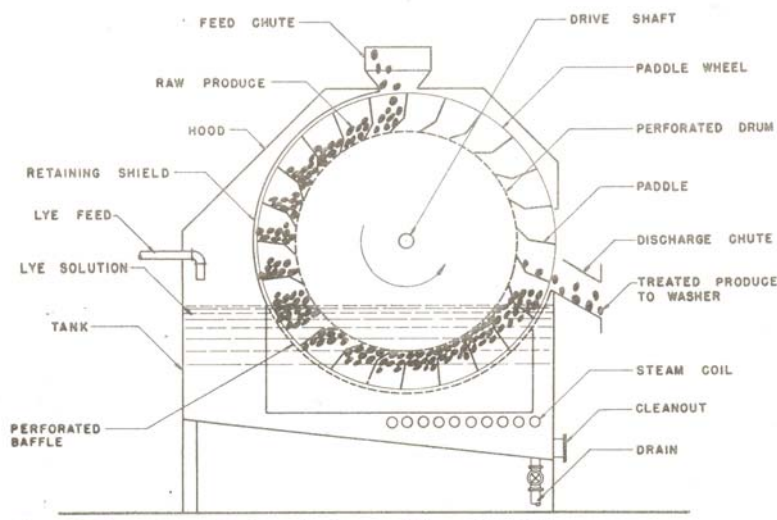


Figure 6.11: Lye peeler

To separate corn oil from corn kernels, the germ portion of the corn first is separated from the rest of the kernel by milling; then the oil is separated from the germ by applying high pressure to the germ in an oil press. Similarly, pressure is used to squeeze oil out of peanuts, soybeans, and cottonseeds. The traces of oil can be removed from the pressed cake by the use of fat solvents. There then remains the separation of the oil from the solvent.

Crystallization is used to separate salt from seawater, or sugar from sugar cane juice. Here, evaporation of some of the water causes super saturation, and crystals form. Since crystals are quite pure, this is also considered a purification process. The crystals are then separated from the suspending liquid by centrifugation.

Newer methods of separation include several techniques involving manufactured membranes with porosities or permeabilities capable of separations and fractionations at the colloidal and macromolecular size level. Ultrafiltration uses membranes of such porosity that water and low-molecular-weight salts, acids, and bases pass through the membrane but larger protein and sugar molecules are retained. This selective separation process, carried out at ambient temperatures, avoids the heat damage to sensitive food constituents that is often associated with water evaporation at high temperatures. Further, removal of acids and salts with the water prevents their concentration, which would otherwise be detrimental to sensitive retained solids.

6.6 RELEVANT STANDARDS

There are many relevant standards developed by the Bureau of Indian Standards, Codex Alimentarius, etc. which needs to be followed for different methods and processes. These can be obtained from respective organizations.



Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Write short notes on the following:

- | | |
|------------|------------|
| i) Slicer | ii) Flaker |
| iii) Dicer | iv) Pulper |

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2. Write short notes on the following:

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| i) Bad mill | ii) Disc mill |
| iii) Roller mill | iv) Colloidal mill |

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6.7 LET US SUM UP

Milling is one of the important unit operations in fruit and vegetable processing industry. A suitable and adequate milling would prove to be a boon for any food industry because a proper selection would reduce the energy consumption and enhance the quality and profitability of a food processing industry.

6.8 KEY WORDS

- Slicing equipment** : It consists of rotating or reciprocating blades which cut the food as it passes beneath.
- Dicing equipment** : Dicing equipment is for vegetables, fruits and meats. The food is first sliced and then cut into strips by rotating blades. The strips are fed to a second set of rotating knives which operate at right angles to the first set and cut the strips into cubes.
- Flaking equipment** : *Flaking equipment* for flaked fish, nuts or meat is similar to slicing equipment. Adjustment of the blade type and spacing is used to produce the flakes.
- Pulping equipment** : *Pulping equipment* is used for juice extraction from fruits or vegetables and for pureed and pulped meats. A combination of compression and shearing forces is used in each type of equipment.

6.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES



Check Your Progress Exercise 1

1. All the short notes should contain the following points:
 - Principle of operation.
 - Suitability of use.
 - Final product and
 - Its relative importance in a food industry.
2. All the short notes should contain the following points:
 - Principle of operation.
 - Suitability of use.
 - Capacity
 - Final product and
 - Its relative importance in a food industry.

6.10 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.
2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.