Technical Bulletin

Post-Harvest Management of Pulses

Rajiv Ratan Lal
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भादअस

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Foreword

The value of pulses in nutritional security, crop diversification and sustainable crop production systems is well recognized. In India, it is far more important as the majority of population is vegetarian, which heavily depends upon cereal and pulse blend to meet energy and protein requirements. Paradoxically, the availability of pulses per capita has progressively declined due to poor growth rate in production. This phenomenon occurred due to marginalization of pulses in wake of 'Green Revolution' and low investment in R&D activities besides huge post-harvest losses. According to an estimate, the post-harvest losses in pulses, from harvesting to milling and storage to transport vary from 25-30%. If this loss is reduced by 50%, an additional 1.5-2.0 million tonnes pulse grains will be available which is almost equal to current import.

In the last few years, concerted R&D activities were initiated to develop technologies to reduce post harvest losses. Milling and storage being the most important post-harvest operations got the maximum attention. As a result, a large number of low capacity *dal* mills were developed to meet milling requirement of small-scale segment of the industry. However, large scale processing more or less remained untouched by scientific innovation and still traditional milling methods and equipments are being used. Some private entrepreneurs have come forward to deal the issue of large-scale pulse processing but high electrical consumption makes adoption tough in such units under Indian conditions. Similarly, sincere efforts have been made to develop technologies for safe storage of pulses and other unit operations. However, information available on different post-harvest operations of pulses is scattered. An effort has been made by Dr. R. R. Lal and Mr. Prasoon Verma to compile the available information in form of this bulletin. I commend their efforts in preparing this manual timely which is quite comprehensive and informative. I believe that this compendium will be very useful to all those involved in production, processing, storage, value addition and trade of pulses.

October, 2007
Kanpur

(Masood Ali)
Director

Preface

Cereals and food legumes are the basic ingredients of Indian diets, especially, for the people with low-income groups, generally live in rural areas. For these groups, food self-sufficiency still remains an unachieved objective. Although India has attained self-sufficiency in the production of cereals but it has to depend on import in case of pulses, which is to the tune of two million tonnes annually, to meet the domestic requirements. This is not always or only because of the inefficiency of the local production systems. The extent of post-harvest losses in case of pulses is estimated to be in the range of 25-30%. Such losses decrease availability, forcing national policy-makers to resort to import of these commodities, which results in many avoidable problems like sudden drop in the prices of imported commodities, and this in turn seriously affect the income of local farmers. Nutritional security in a developing country like India can be achieved by reducing post-production losses.

In past, efforts have been made largely for improving the yields rather than enhancing the post-harvest management of the commodity. This has led to some paradoxical situations. Indeed, even though the technical conditions for increasing production have, by and large, been met, the desired impact could not be seen due to post-harvest obstacles. In fact, production improvement must match with improvement in post-harvest operations and prevention of post-harvest losses. Information on post-harvest management of pulses is meagre and scattered. Therefore, efforts have been made to compile the information available on various aspects of post-harvest technologies in pulses. Herein general basic information on different pulses have been complied. It covers the total process from harvest to consumer, from determination of physiological maturity to marketing of products, which makes up the complete "post-harvest system". Operations of harvesting, drying, threshing, storage, milling and transport of the principal pulse grain, have been discussed in detail. Experiences or solutions resulting from the use of traditional methods, suitable technologies and mechanized systems are also discussed in detail.

This bulletin will be useful to field staff, extension workers, rural entrepreneurs, processors and developmental agencies, engaged with the implementation of projects aimed to improve post-harvest operations of pulses. It is also meant for the pulse producers, who have only partial and generally insufficient understanding of post-harvest problems. This manual will also be of interest in one way or other to all those working for nutritional security of the country. This publication will be of great help in unifying the post-harvest aspects of pulses and dissemination of the knowledge.

Authors express their sincere gratitude to Dr. Masood Ali, Director who was instrumental in bringing out this manual. He took great pains in going through the manuscript and make the contents in presentable form. Critical and analytical inputs from Mr. Sanjay Kumar Garg are duly acknowledged.

R. R. Lal

October, 2007 **Prasoon Verma**

Contents

1. Introduction

Importance of pulses

Pulses are the cheapest and rich source of protein which can be considered as lifeline for vast vegetarian population of India. Apart from being the good source of protein, pulses also contain substantial quantity of minerals, vitamins, crude fiber etc. Amino acid composition of pulses is complementary to that of cereals. Mixed diet of cereals and pulses, which form staple diet to majority of Indian population, is of the superior biological value than either taken separately. In India, pulses are the second major source of dietary protein (27%) after cereals (55%). The share of animal protein is as low as 18% (Ali N, 2003). In addition to meeting the protein needs of the human population, pulses are also essential for the health of soil. Each plant of the pulse crop fixes atmospheric nitrogen in their root system, which enables plant to meet its own nitrogen requirement. Benefits of this nitrogen fixation percolate to the succeeding cereal crops. By-products of pulse plants are an excellent fuel and feed. Besides providing human nutrition and soil recuperation, pulses are important for sustainable agriculture.

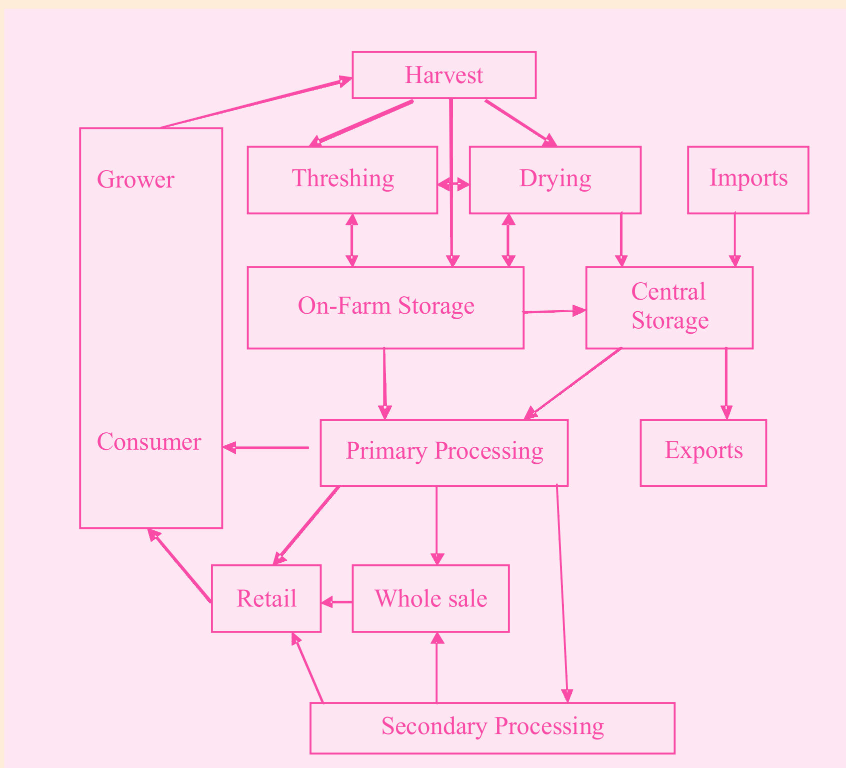
A standing crop in the field, ready to be harvested, is always a treat for farmers who depend so heavily on the yield of the ensuing crop. But it turns out to be a great disappointment if after the harvest, a large part of the produce gets lost, or deteriorate so badly that it becomes unfit for marketing and human consumption. Pulses are not exception, rather more vulnerable to it. Way must be found to know what all happened, and when? And above all, what can be done to avoid post-harvest losses? Before attempting to answer these questions, it will be better to briefly discuss the series of operations, which the pulse grains have to undergo after the harvest.

2. Post-harvest Systems of Pulses

What constitutes the post-harvest system?

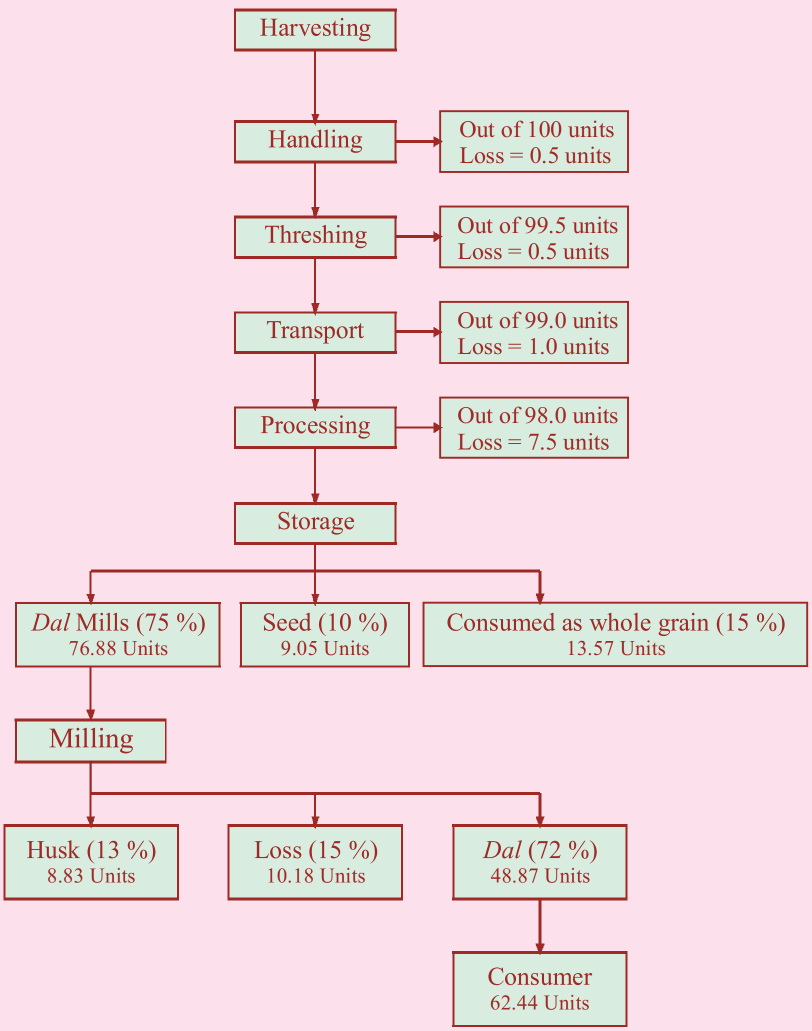
In the whole food chain of pulses, harvesting is the first stage between the theoretical and actual agricultural production which can either be done manually or with the help of machines. But in both the cases, the harvesting should generally not take place until the grain has reached its optimal maturity. After the harvest, it may be necessary to dry the crop before the subsequent threshing operation. The grain, then, must be cleaned and dried, so that it can be stored or undergo further processing. Grains can be stored in bulk or bags, on the farms or with storage agencies. Depending upon requirements, this may even be stored in household storage structures for domestic consumption. Finally, the grain is sent from the place of storage to market for sale to consumers, to small-scale food processors, to commercial *dal* mills or to other agro-food industries. From these mills, the processed *dal* or other products are sent to consumers through wholesalers or retailers. The sequence and interactions of these operations constitute a complex system called the post-harvest system.

The pulses post- harvest system



Post-harvest profile

At every stage of pulse food chain, some losses take place. The extent of the loss depends upon a number of factors, which will be discussed subsequently. A complete profile of post harvest operations of pulses is shown below which depicts the number of units that is actually available to the consumers out of total production.



Post-Harvest Profile of Pulses

2.1 Technologies and phases of the post-harvest system for pulses

Available technologies

Different technologies for post harvest operations of pulse crops are available, traditional or improved, employed at various phases of post-harvest system depending upon the resourcefulness of the farmer growing the crop. A list of such operations are depicted in the Table 2.1 below :

Table 2.1 : Traditional and improved technologies for post-harvest operations.

Post-harvest operations	Traditional technologies	Improved technologies
Harvest	Manual	Manual and mechanized
Pre-drying	Standing or in shocks	Standing or in shocks
Storage of harvested crops	In fields or on threshing floor	In fields or on threshing floor
Threshing	Manual	Mechanized
Pre-cleaning	Hand winnowing	Mechanized
Drying	Natural	Artificial
Cleaning and sorting	Winnowing in the wind	Mechanized
Storage of grains	In traditional granaries	In bags or in bulk
Processing/Milling	Manual	Mechanized

2.2 Post-harvest losses

Definition of post-harvest loss

The expression "post-harvest losses" means a measurable quantitative and qualitative loss in a given product occurred during the various phases of the post-harvest system. In economic terms, sum of the losses in quantity and quality of the products inevitably leads to loss of money. In addition to direct economic losses, some losses result from poor management of post-harvest systems.

Post-harvest system and losses

Seeds of poor quality, inappropriate farming practices and insect infestation in the field can obviously cause loss of produce even before harvest. From the harvest onward, the grain undergoes a series of operations during which quantitative and qualitative losses may occur. Table 2.2 indicates the type of losses that take place at prevailing conditions at various stages of post-harvest system.

Table 2.2 : Type of loss at different post harvest stages

Stage of operation	Type of loss
Late harvest	Shattering losses, losses due to attack of birds and other pests
Insufficient drying of grain	Losses due to development of moulds and insects
Improper threshing	Broken grains and threat of insect development at a later stage
Poor storage	Losses caused by combined action of insects, moulds, rodents and other pests
Improper milling	Broken and powdering loss
Transport	Quantitative loss
Defective packaging	Quantitative and qualitative loss

Extent of losses

The extent of losses that takes place at different stages of post-harvest chain differs from grain to grain. Reliable data on the true level of post harvest losses are not available. The extent of loss may fluctuate considerably depending upon weather conditions, varieties, locations and the processing and storage techniques employed. However, according to rough estimates made by different workers (Kurien *et al*., 1972; Birewar, 1982; Kulkarni, 1986; Jeswani and Baldev, 1990) total post-harvest losses in case of pulses are in the range of 25-50% (Table 2.3). The major loss is caused at the stage of storage and milling. As per the estimated 15 million tonnes (mt) of pulse production, 75% *i.e.*, 11.25 mt goes for milling. Taking 15% milling losses into account, 1.69 mt of produce is lost in milling alone, which if saved by adopting improved milling methods and machineries, will marginalize the import requirement of the pulses and save significant amount of foreign exchange.

As the husk forms 10-16% of grains, a theoretical *dal* yield of 84-90% should be possible during milling (Kurien, 1979). Commercial milling of pigeonpea yields 76.1% *dal* against theoretical yield (Khare *et al*. 1966). It has also been observed that 54% of the kernel had their edges chipped off. The chipping occurs both in roller and sheller mills. The germ, which forms about 2-5% of the grain is also lost during splitting. It has been observed that the peripheral region of the pigeonpea grain kernel is richer in protein than core (Reddy *et al*., 1978; Narsimha, 1984; Lal, 1999). As most of the milling losses *viz*. broken and powder) are contributed by outer region, the actual loss in qualitative terms would be even higher. The present high milling losses can be attributed to the fact that the unit operations involved in milling are mostly scaled-up versions of the traditional household pulse milling methods. A systematic and logical technology development for the complete pulse milling process has not received adequate attention. Attempts have remained confined to a few unit operations and system components only.

After milling, storage is another important aspect in post-harvest sector, as it causes tremendous loss to the availability of pulses. Being rich source of protein, pulses are easily attracted by storage insects. Controlling milling as well as storage losses together can meet at least present import requirement of the country.

Table 2.3 : Estimated post harvest losses of pulses

Stages	Losses (%)
Harvesting	1.0-3.0
Handling	1.0-7.0
Threshing	0.5-5.0
Drying	1.0-5.0
Transport	0.5
Primary Processing	1.0
Storage	5.0-10.0
Milling	15.0-20.0
Total	25.0-50.0

2.3 Types of losses – their nature and prevention

Types of losses

Losses in the entire post-harvest chain of pulses could either be in the loss of weight, quality or the economic loss. Different forms of losses and reasons that are responsible for these losses are discussed briefly.

Losses in weight

The loss in the weight of grain does not necessarily mean a loss of product. Loss of weight results in reduction of physical substance of the product. For instance, the decrease of the moisture content brings about a lowering of weight, but this is not a food loss. On the contrary, an increase of weight by absorption of moisture due to rains or high humidity can cause severe damage and thus, is a considerable loss. Weight losses take place mainly due to prolonged action of pests (insects, birds, rodents), or due to leakage of products (perforated bags, spillage during grain handling *etc*.) and can occur at any stage during the harvest, storage and transport or handling.

How to measure the weight loss?

In order to recognize the weight loss, an equal volume of damaged and healthy grains should be taken. Grind both the samples, and weigh the flour obtained in each case. It will be observed that the damaged sample produces less flour. This method can also be useful for avoiding potential weight frauds, since it is easy to augment weight by dampening the grain or by adding foreign bodies like pebbles, earth or sweepings.

Losses in quality

The quality of grains can be ascertained on the general principle according to which grains must be "wholesome, sound, odorless and of market quality". The criteria of quality vary widely and involve the exterior aspect, such as, shape, size, smell and taste. A clean wholesome product is of primary importance in marketing. An experienced trader can easily predict the quality by taking a handful of grains from a bag. The presence of a floury dust will indicate the presence of insect infestation or the presence of a bad smell can lead to suspected rodent attacks, which can be confirmed by the presence of rats or mouse excreta or hairs. Losses in quality are, thus, evidenced by a decrease in the market value of the grain.

Criteria for quality evaluation

The quality of grain can be ascertained based upon some well laid tests, measurements and laboratory analyses. Important among these criteria are based upon standards related to the physical condition of grain and to its food, nutritive and germinative values.

How to evaluate the quality of grain?

The quality of a given batch of grains can be evaluated by :

- Moisture content : suitable for the storage or further handling of the grain
- Colour : homogeneous and appropriate to the type of grain under consideration
- Odour : it must not hint that any biochemical change is going on
- Cleanliness : the number of impurities must conform to established standards of quality
- Infestation : the absence of insects or other living organisms must be ascertained

Generally, multiple criteria are combined to define the quality of the products. The quality criteria may vary according to eating habits of the community. Losses in quality are mainly the result from mechanical injuries sustained by the grains during processing operations, the action of pests (insects, rodents) and micro-organisms (moulds), or the chemical changes produced within the grains under the effect of environmental conditions (temperature, humidity, duration of storage). These losses can occur at any stage of production, especially during hot and humid climatic conditions.

Losses due to physical condition

These depend on the physical condition of the grain during a given stage of the post-harvest system. The physical characteristics generally considered in evaluating the incidence of such losses are : shape and size of the grains, percentage of moisture, presence of impurities (foreign grains, grains that have germinated, broken, deteriorated or damaged, pebbles, earth, plant residues, fragments of glass or metal, animal hairs or excrement, *etc*.), degree of infestation by insects or micro-organisms.

Losses due to change in food qualities

These losses are caused due to alteration of the organoleptic features like taste and smell, presence of toxic products such as toxins, pesticide residues, *etc*., and from alteration in its content of proteins, carbohydrates and other important nutrients. These are especially critical when the grains are intended for human consumption.

Losses due to change in germinative properties

The grains that are to be used for seed purposes, must have a minimum of germination percentage standardized for that particular grain. Seeds should have good vigour, good growth rate of seedlings and absence of anomalies in the plants thus obtained. The alteration of these properties results into production losses by decreasing the capability of the grain to germinate.

Economic losses

Economic loss results not only due to deterioration in the quantity or quality of the grain but is also influenced by some factors within the post-harvest system that can hamper the growth of production and income. These include production systems, work schedules and methods, infrastructure, organization models, credit mechanisms *etc*. For example, adoption of mechanized or semi-mechanized systems for some operations (harvesting, threshing, drying, *etc*.) can cut working time while, at the same time, permitting an increase in production by reducing the labour required and exploiting the land to better advantage. Commercially, if the transport system is inadequate, the farmer may find it impossible to sell the produce within the required time-limits and in the places where market prices are the most attractive. The fact of having to forgo a potential profit is loss of money beyond doubt. If a farmer is not able to store the produce in complete security in available storage facilities, the produce need to be sold immediately after the harvest, thus making farmer unable to earn profit through selling the produce at maximum market prices. Once again, missing a profit is an economic loss for the farmer. The sequences of such situations often go beyond individual losses. This affects the production and the economy of entire nation.

3. Harvesting

What is harvesting?

Harvesting is the operation of gathering the useful part or parts of the plant and is carried out at the time when all the nutrients have developed and the edible parts have reached the appropriate degree of maturity.

In general, the harvest takes place 10 or 15 days after the grain has reached physiological maturity. At the time of maturity, the grain has specific moisture content and special physical characteristics. The most appropriate time of harvest is determined based upon the length of the growing cycles (which differ according to the crop and varieties) and also the degree of maturity of the grain.

When to harvest?

The following Table 3.1 shows the degrees of moisture content considered appropriate for good harvest conditions and the characteristics permitting assurance of physiological maturity:

Table 3.1 : Maturity indices for different pulse crops

Grains	Physical characteristics
Pigeonpea	Pods ripe and black. Lower leaves start falling.
Chickpea	Dried stems and leaves, hard grains resistant to the thumbnail.
Urdbean	Pods ripe and black, shells dried
Mungbean	Pods ripe and black, shells dried
Rajmash	Leaves yellow, shells dried
Lentil	Upper leaves dry and pods pale yellow
Fieldpea	Upper leaves dry and pods pale yellow

The harvest should take place at a time when the grain has moisture content in the range 15-20%. Clearly, the higher the moisture of the grain at harvest time, greater the risks of losses from moulds, insects and germination. On the other hand, the longer the grain remains in the field (for further drying of the product), the greater are the risks of losses due to shattering of grains, or from attacks by birds, rodents and other pests.

3.1 Harvest operations

Hand harvesting

Harvesting of pulse crops is generally done by hand with simple farming implements like sickle or by machines when the pods are ripe but not yet open. To harvest the pulse crops by hand, the plants are pulled up and allowed to pre-dry in the sun. This operation should be done early in the morning, while the dampness of the night minimizes the risk of shattering losses. In some places, before the harvest, the plants are treated with chemical defoliants. This treatment is intended to hasten drying of the plants and reduce the quantity of plant matter to prevent its slowing up threshing operations. On an average, it takes about 80-100 man-hours per hectare to cut the plants by sickle.

Mechanized harvesting

Mechanized harvesting of legumes is usually done with combine-harvesters designed for wheat but adapted for pulses crops. However, it be used only in large fields and that too which has been levelled before sowing and then planted with varieties which are erect in nature and reach maturity simultaneously. The capacity of these machines generally varies from 0.9-1.1 h/ha. Mechanized harvesting in case of pulse crops is minimal due to unavailability of mechanical harvesters at affordable price. However, some designs of reapers are available which can be used for harvesting of chickpea. The use of such machines should be encouraged to cut down the cost of harvesting and thereby reducing the cost of production.

4. Pre-drying

What is pre-drying ?

"Pre-drying" is the stage of the post-harvest system during which the harvested product is dried in order to undergo the next operation of threshing, under the best possible conditions.

Why is pre-drying important ?

At the time of harvesting, the cut portions of the plant may contain too much green plant matter and all the grains may not have reached a uniform degree of maturity and may have moisture content too high. This makes pre-drying essential.

How to pre-dry?

Pre-drying can be done in two ways :

1. Once maturity has been reached, allow the crop to pre-dry, standing in the field, before harvesting. But some inherent dangers are associated with this method of pre-drying. This may lead to :

- shattering losses of grains
- losses from attack by pests (rodents, birds, *etc*.)
- losses from infestation (insects, moulds, *etc.*)
- prolonged occupation of the field creats problems for using the land for a second crop

2. Place the newly-harvested crop piles, in the field or on drying-floor. Prolonged exposure to the air (in sun or shade) reduces the moisture content of the grains to desired level. The shape and size of these piles can vary according to the crop to be pre-dried. However, following precautions must be taken :

- Protecting the piles from sudden rains or nocturnal humidity and dew is essential in order to avoid repeated dampening of the shells and grains during pre-drying.
- Direct contact of the grains with the ground must be avoided in order to cut down the risks of infestation (moulds, *etc.*).

5. Threshing

What is threshing?

"Threshing" is the operation of separating the grains from the plants. These operations may be carried out in the field or on the threshing floor, by hand or with the help of animals or machines. Whatever the system used, it is very important that threshing be done with care. Otherwise, these operations can cause breakage of the grains or protective husks, thus reducing the quality of product and subsequent losses from the action of insects and moulds. Care should also be taken while transporting the harvested crops from the field to threshing floor to avoid any loss.

Hand threshing

Hand threshing is generally done in case of pigeonpea. One of the simplest systems for threshing of pigeonpea crop is to strike the sheaves of crop spread over threshing floor with a flail or a stick. While this method can be adopted for other pulse crops like chickpea, mungbean, urdbean, fieldpea, *rajmash* and lentil but a more convenient method is threshing with animals or vehicles. The threshing-floors on which the sheaves are spread must have a hard, clean surface. By using method of hand-threshing, a worker can obtain 15-40 kg of product per hour.

Threshing with Animals or Tractors

Subject to the availability of draught animals, large quantity of crops can be threshed by treading the animals over about 30 cm thick layer of sheaves. This operation, which is also called "treading out", can equally well be accomplished with vehicles. Grain is obtained by running the tractor twice over sheaves of harvested and dried crops that are spread in layers on a circular threshing floor 15-18 m in diameter. The sheaves must be turned over between the two passages of the tractor.

Threshing with hand-driven machines

Normally a hand-operated machine like Olped thresher, which is basically used for threshing of paddy can also be used for threshing of cut stocks of pigeonpea. By means of the handle or pedal, a big drum fitted with metal rings or teeth is made to rotate. The cut-stocks of pigeonpea is threshed by hand-holding the sheaves and pressing the upper portion of dried plants against the rotating drum. The speed of the threshing drum must be kept at about 300 revolutions per minute (rpm). The hand-held sheaves must all be of the same length with the panicles all laid in the same direction, and the grains must be very ripe and dry. The machine must be continuously and regularly fed, but without introducing excessive quantities of product. Use of these threshing machines may require two or three workers. Depending on the type of machine, the skill of the workers and organization of the work, yields can be estimated at a maximum of 100 kg/h.

Threshing with motorized threshers

The use of motorized threshers or threshers operated by tractor power has become very common for threshing of pulse crops. The threshers available in the market are basically designed for threshing of cereal crops and no specific thresher is available for threshing of pulse crops. However, by the simple replacement of a few accessories and the appropriate changes in settings, these machines can be used for threshing of pulse crops as well. Few popular designs of cereal threshers like Amar thresher, CIAE Multi-crop thresher and Sonalika threshers have been successfully used for threshing of pulse crops with some degree of variations in the grain recovery. Table 4.1 shows the principal technical features of these machines and the yield obtained in case of different crops. Equipped with a rotating threshing drum (with beaters or teeth) and a stationary counter-thresher, these machines often have devices to shake out the straw and to clean and bag the grain. Whether self-propelled or tractor-drawn, these threshers are often mounted on rubber wheels for easy movement to the field. The use of motorized threshers may require two or three workers. Yields depend on the type of machine, the nature and maturity of the grain, the skill of the workers and organization of the work.

Table 4.1 : Threshing capacity of different threshers

Threshers	Technical details	Suitable for	Capacity (kg/h)
Sonalika	25 hp tractor, Peg type, Single blower	Chickpea, Lentil	300-350
Amar	7 hp motor, Peg type, Double blower	Pigeonpea, Chickpea, Urdbean	100-350
CIAE	7 hp motor, Peg type, Double blower	Chickpea, Lentil	300-450

6. Drying

Why is drying important?

After threshing, the moisture content of grains remains generally higher than the desired for safe storage of grains (13-14%). Drying is the phase of the post-harvest system during which the product is rapidly dried until it reaches the "safe-moisture" level. The aim of drying is to lower the moisture content of the grain for safe storage and further processing.

Methods of drying

For drying grain, essentially two methods, *viz.*, natural drying and artificial drying are used.

Natural drying

The natural drying method consists essentially of exposing the threshed products to the air (in sun or shade). To obtain the desired moisture content, the grain is spread in thin layers on a drying-floor, where it is exposed to the air. The duration may vary depending upon the moisture content required for safe storage. To achieve uniform drying, the grain must be stirred frequently, especially if it is in direct sunlight. Furthermore, for drying to be effective, the relative humidity of the ambient air must not be higher than 70%.

Some important points to remember :

- Grains must not be exposed at night. In fact, by bringing about an increase in the relative humidity of the air, the grains get re-humidified.
- This method should not be used in humid regions or during the rainy season.
- It must be remembered that insufficient or excessively slow drying can bring severe losses in product during storage from the self-generated heat of "green" grain.
- Finally, prolonged exposure of grain to atmospheric factors, results into pest attack (insects, rodents, birds) and micro-organisms (moulds) development.
- Grains should be sun-dried in the middle of the day only (when air is dry).
- Do not dry grains in bags on a concrete floor. Use bag dryer which forces heated air through the grains in sacks.

Advantages

- Very low initial cost
- Reduces the cost of drying
- Flexible capacity

Disadvantages

- Slow drying process
- Depends on the weather
- High risk of contamination
- Possible loss due to birds and rodents
- High labour input

Artificial drying

In artificial drying, heated air (dryers) or unheated air (dehumidifiers) is blown through a grain mass.

Forced hot-air drying

This is the most wide spread practice in semi-humid and humid conditions where natural drying cannot be used. Artificially heated air is forced to flow through a mass of grain in bulk or in bags to absorb released moisture from grain mass.

Advantages

- Facilitates early harvesting
- Reduces shattering losses in the field
- More rapid drying in terms of capacity
- Independent of weather conditions

Disadvantages

- Heavy initial cost
- High cost of drying
- Risk of seed damage due to high temperature
- Requires skilled personnel and regular monitoring
- Risk of breakdown or fuel shortage at critical times

Dehumidified air-drying

In case of dehumidified air-drying, unheated dehumidified air is circulated through the grain mass, until the moisture content of the grain is reduced to the desired level. It is more commonly applied when small quantities of grain must be dried to very low moisture content for being used as seed.

Advantages

- Easy and simple to manipulate
- Low risk of seed damage from hot air

Disadvantages

- Not suitable for large-scale production
- High cost of investment

Drying systems and types of dryers

For artificial drying of grains, two types of dryer are used :

1. Static or discontinuous dryers or batch dryers

These types of dryers are comparatively less expensive and can handle only modest quantities of grain, thus they are better suited for small and medium scale centers for the collection and processing of grains. Three following types of batch dryers are generally used :

- **Floor dyers :** Suitable for all grains of all sizes.
- **Bag dryers :** Suitable for small grain lots to be used as seed where many varieties are handled (breeder and foundation seed). All types of grains in sacks.
- **Box dryers :** Suitable for large grain lot where slow drying is required.

2. Continuous dryers

These are high-flow dryers that need a more complex infrastructure, complementary equipment and special planning. They are, therefore, more appropriate for big centers, silos or warehouses, where very large quantities of product are handled. Continuous dryers are generally of three types :

- **Continuously flowing vertical dryers :** Suitable for quick and normal drying and free flowing grains of single variety. Can handle large volume of grain. Not suitable for small lots of different varieties.
- **Continuously flowing belt dryers :** Suitable for quick and normal drying seeds, small to very small lots and chaffy seeds.
- **Rotary dryers :** Suitable for quick and normal drying grains, chaffy grains with moderate moisture. Suitable for large capacity drying. Not suitable for grains with high moisture.

How to choose an appropriate drying system?

The selection of a suitable drying system depends on the following factors :

- **Drying capacity :** Capacity of the dryer should be sufficient enough to handle the volume of grain to be dried.
- **Initial investment :** Initial cost and maintenance cost.
- **Fuel and Power :** Availability and cost.
- **Kind and chemical composition of grain :** Grains are of three types based on their tendency to release excess moisture :
  - ❑ Slow drying grains (maize, rice, legumes, lupin)
  - ❑ Normal drying grains (cereals)
  - ❑ Fast drying grains (sugar beet, grass seed)

- **Size of the grain lot :** How the grain is to be delivered (bulk, sacks).
- **Moisture content** : Initial and the desired moisture content after drying.
- **Flowing properties of the grain :** There are two main categories: Free flowing grain and grains with poor flowing characteristics such as chaffy seeds.
- **Temperature and relative humidity of the ambient air :** Cool and damp weather will increase the drying cost, whereas same will be much less in hot and dry weather.

7. Storage

What is storage?

"Storage" means keeping the products in a manner that guarantees food. Over a period of time, all stored foods will degrade in nutrients and palatability until it reaches the inevitable end where it is not safe even for the animals.

Pulses can remain in edible condition for several years, if properly stored. However, pulses are more difficult to store than cereals and suffer much greater damage from insects and microorganisms. This not only results in quantitative losses, but also in qualitative reduction of the nutritive value because of vitamin loss and deterioration of protein quality. The milling losses in insect-damaged grains are even higher as more breakage and powdering occur with such grains. Pulses are susceptible to infestation, both in the field and during storage, by weevils, which are prolific, breed rapidly, and cause serious deterioration in the nutritive value of the grain. Damage ranging from 30-70% of the grain has been reported in various publications. At 30 °C and 70% relative humidity (RH), some species of bruchids take only a few weeks to develop from egg to pupa. Higher humidity are conducive to more rapid proliferation of all species.

Influences of environmental factors

To conserve the quality of products over long-term storage, degradation processes must be slowed down or even stopped. Degradation of grains during storage depends principally on a combination of five factors *viz.* time, temperature and humidity, moisture, oxygen content and light. During storage, as during other phases of the post-harvest system, the combined effects of these factors can sometimes cause severe losses.

Interaction between grain moisture content, temperature and relative humidity

Most important factors of grain deterioration are the interaction of temperature, humidity and moisture, which are the determining factors in accelerating or delaying the complex phenomena of the biochemical transformation (especially the "breathing" of the grain) that are the basic origin of grain degradation. Furthermore, these have a direct influence on the speed of development of insects and microorganisms (moulds, yeasts and bacteria), and on the premature and germination of grain without season. In general, the higher these three factors are, the more rapidly the grain deteriorates.

Grain moisture content is associated with ambient relative humidity. Grains are hygroscopic in nature and absorb or lose moisture from or to the atmosphere until seed moisture content and atmospheric relative humidity reach the equilibrium. Grains reach a moisture content equilibrium with the

RH of the air, not with the absolute humidity. Equilibrium level varies according to:

- **Ambient temperature :** The lower the temperature, the higher the moisture content of seeds at a given relative humidity.
- **Chemical composition of the grain :** The equilibrium moisture contents of different grain lots at the same RH will not be the same. Grains differ in their chemical compositions (lipid, protein, starch). Oils do not absorb moisture, protein absorb the most water per unit of weight, and starch absorbs less than proteins.
- **Hysteresis** phenomenon.
- **RH of the ambient air :** It is the main determinant of the grain moisture content.

Some important tips

- The best way to increasing the shelf life of stored grain is to lower the temperature of the area of storage. The storage lives of most foods are cut in half by every 10 ºC increase in temperature.
- The temperature of the storage area, if possible, should be below 25 ºC but above freezing temperature. Similarly, the relative humidity of the storage chamber should be of 15% or less, especially when grains are stored for seed purpose.
- For each 1% reduction in moisture content, the storage life of grain is doubled, when grain moisture content is between 5 and 14%.
- For each 5 ºC lowering of storage temperature, the storage life of the grain is doubled, when temperature is between 0 and 50 ºC.

7.1 Storage methods

Choice of storage methods

There are basically two methods of storage : in bags and in bulk. Bags can be stored either in the open air or in warehouses, bulk grain is stored in bins or silos of various capacities. The choice between these methods and the degree of technological sophistication of the storage buildings depend on many technical, economic and socio-cultural considerations. The traditional storage systems used by small farmers is the most widely used structure. These systems are fabricated with the use of artesian construction techniques and local materials.

Storage in bags

This method consists of conserving dried and cleaned grain in bags made of plant fiber or plastic, and neatly stacking the bags in carefully prepared areas. This method is little used in developed countries but is widespread in developing countries. It is economical and well-adapted to local grain-transport and marketing conditions. There are several ways of storing grain in bags. The bags of grain can be stacked outdoors under tarpaulins, or placed inside storehouses, sheds or warehouses. Sometimes, especially for seeds, grain is stored in bags in refrigerated warehouses.

Outdoor storage

These are storage systems in which the bags are not stacked in solidly constructed buildings. The main systems of open-air storage are : storage in pyramids, and storage in flexible silos. The advantage of these systems is that they can be set up quickly and fairly easily. For this reason, they are generally used when storage needs are specific and urgent.

Storage in pyramids

This system is often used for short-term storage in dry areas. It consists of stacking bags in pyramids on platforms that can be protected in case of bad weather. The platforms on which the bags are stacked must effectively protect the grains against termite attacks. Covered by concrete or tar or made up of a layer of building-blocks covered with tarpaulins or plastic, the platforms must prevent the grain from exposure to rising damp. To achieve this end, not only the sites of the storage areas must be carefully chosen but drainage ditch for rain-water runoff must be dug around the platforms. To keep rain-water from falling on the grain, it is important to cover the pyramids of bags with tarpaulins.

Storage in flexible silos

Storage in flexible silos is often used for setting up a security reserve and is very similar to storage in pyramids. The main difference is the greater complexity of the storage facility. A flexible silo is made on a concrete platform, generally circular in shape. Walls of galvanized screening about 2.5 meters high are erected around it and the inner walls lined with a thick film of plastic. On the outside, about 50 cm from the walls, galvanized metal sheets about 1 m high surround the silo to protect the grain from rodent attacks. The bags stacked in the silo are covered with a conical tarpaulin attached to the walls and kept in place by a system of ropes. Because these buildings are almost completely sealed, it is important to store the grain when it is very dry. Flexible silos of 500 tonnes are the most common, but some are also built with storage capacities of 250-1000 tonnes. The costs of building these silos are fairly modest, but their useful life is relatively short, seldom exceeding five years.

Warehouses and storehouses silos

To store grains, warehouses are used to stack the bags. Periodical checking of the stored lots is done for timely spray of insecticides for any visible insect activity. At rural levels, even huts are used to serve the purpose. A warehouse must prevent the grains from getting wet, protect the grains from high temperatures, prevent the access of insects, rodents and birds, facilitate monitoring of stored grain, permit timely insecticide treatment of bags and premises and facilitate the care of equipments used to move and transport the bags. For effective protection of stored grains against atmospheric factors (sun, rain, humidity) and smooth operation of storage, systems must be located in relatively dry sites not prone to flooding, outside towns, near to electricity and water distribution systems, aligned on a north to south so that the sides with the smallest area get the strongest sun.

Bulk storage

This method consists of storing unpackaged grain in structures built for this purpose (bins, silos). The types of construction vary. There can be relatively simple low capacity structures for storage of agricultural surpluses in production areas, or large complex installations for commercial or industrial storage of products. In general, there are two categories of bulk-storage structures : low capacity silos or bins for storage on the farm and high capacity silos. Bulk storage is quite popular in developed countries as it significantly curbs storage losses, but in developing countries like India, high initial investment and lack of bulk material handling systems prevent wider adoption of this technology.

Low-capacity silos for farm storage

On-farm storage for home consumption is the basic form of rural storage in India. There are several types of traditional storage structures, each adapted to the climate of the region. Their common feature is the use of locally available materials. Improvements have been made in the construction of earthen granaries by mixing small quantities of cement with the earth or giving smooth finish to the silo walls. Silos made of bricks are easy to construct and maintain. Concrete, reinforced concrete, or metal silos have also gained popularity in rural areas. Metallic bins have become a household item in recent past. In view of their low capacity, metal drums are best adapted to rural storage. The security of metal bins against rodent and features of air-tightness make the bins more versatile.

High-capacity silos

High capacity silos are complex structures intended for the commercial or industrial storage of large quantities (several thousand tonnes). Two types of silos are quite common in use, vertical or horizontal silos. Vertical silos are made up of several sheet metal or reinforced concrete storage bins stacked vertically. This category includes silos composed of round bins made of flat or corrugated galvanized sheet metal, polygonal bins made of painted or galvanized metal panels and round bins made of reinforced concrete. Horizontal silos are also made of sheet metal or concrete and are composed of juxtaposed square or rectangular bins laid horizontally. The relatively common round metal bins require less investment and are easy to erect. Polygonal bins are similar to round ones and their diameters are easily adjustable. Round concrete bins guarantee good thermal insulation and permit much higher vertical stacking that can be obtained with metal bins. Square or rectangular bins are generally flat bottomed. Such bins require a higher per quintal investment but make the best use of the available sites. In order to avoid the disadvantages of a potential rise in temperature and to guarantee good storage, storage bins are often equipped with aeration systems. Ventilation systems can be used to lower the temperature of the grain in order to slow down biochemical degradation processes (cooling ventilation), to keep the grain at a constant temperature, by systematically evacuating the heat produced by the grain mass itself (maintenance ventilation) and to dry the grain slowly (drying ventilation). It can also be used to fumigate the bin whenever any insect activity is observed. In addition to that, in airtight silos oxygen level depletes due to respiration of grains or living insects and microorganisms, this is called controlled atmospheric storage, making internal atmosphere difficult for survival of insects. Injection of inert gases (nitrogen, carbon dioxide) in airtight structures is also followed as a technique to control infestation within stored mass. Despite the obvious advantages of these storage systems, airtight silos still have limited distribution because of technological complexity especially for the high capacity bins.

8. Stored Grain Pests and Their Control

Insects-pests of stored pulses

The most important insect damaging pulses in field and storage are referred as bruchids or pulse beetles. The genus *Callosobruchus* has large number of species representing *C. maculatus* (Fabricius), *C. chinensis* (Linnaeus), *C. analis* (Fabricius) and *C. phaseoli* (Gyllenhal) are more common in subtropical regions. However, *C. rhodesianus* (Pic) and *C. sunnotatus* (Pic) are also present in tropical region. *C. theobromae* (Linnaeus) is also found in pods of pigeonpea in India. *Acanthoscelides obtectus* is serious pest in *rajmash*. Other insects pests which cause damage to stored legumes are *Trogoderma granarium* (Everts), *Rhyzopertha dominicia* (Fabricius), *Tribolium castaneum* (Herbast), *Ephestia cautella* (Walker), *Corcyra cephalonica* (Stainton), *Latheticus oryzae* (Waterhouse), *Lasioderma serricorne* (Fabicius), *Stegobium paniceum* (Linnaeus), *Oryzaephilus surinamensis* (Linnaeus), *Cryptolestes ferrugineus* (Steph) and few species of mites. Fungi from genera *Penicillium* and *Aspergillus* in association with these insects enhance the rate of deterioration. In India, pulses are mostly consumed in form of *dal* or dehusked split, which in absence of seed coat are prone to moisture gain and fungal infestation, besides preferred by insects other than bruchids. The split pulses are attacked by *Rhizopertha dominica*, *Trogoderma granarium*, *Tribolium castaneum* and *Cadra cautella* under storage conditions. The losses due to insect activity during storage are physical loss, loss in carbohydrates and proteins, nutritional losses and contamination of product with uric acid, fragments and faecal matter.

Grains damaged due to bruchid infestation

Sources of infestation

There are several sources of infestation :

- Fields
- Carried-over commodities, waste and rejects
- Agricultural machineries
- Processing plants
- Farm grain stores and re-used sacks
- Means of transportation
- Alternative hibernation sites and hosts

Basic steps for insect control

In order to control insects in a storage warehouse or processing plants the following steps must be followed:

- **Monitoring :** Have an inspection or surveillance programme which will yield prompt awareness of a possible problem (presence, level, source) before it occurs
- **Identification :** Determine the extent and nature of the possible problem (species, type, level, means of transmission)
- **Control :** Devise a plan for controlling the problem (integration of all possible means to achieve good, cheap and safe pest control)

Monitoring-tools for infestation detection

The easiest way to avoid damages by insect pests is to prevent their occurrence and spread. Inspection and monitoring are excellent tools for early detection of insect infestation.

Inspection : It should be carried out frequently and thoroughly to detect actual problem or the potential of it and evaluate its seriousness. It is important that it is scheduled routinely and is carried out by trained and qualified staff who has adequate knowledge about the stored-grain pests.

Monitoring insect infestation : Monitoring for insect infestation should be carried out as per the following method(s) :

- Visual observations involving sampling, sifting and counting
- Detection of latent infestation through chemical, x-rays and sound amplification
- Use of chemical attractants : Synthetic pheromones and food attractants are valuable where insects are difficult to locate and their population is hard to assess
- Use bait stations : Attractive sticky food, especially for moth and beetles
- Use of traps : Light traps function as an early warning monitor system-nets, aspirators may be used
- Combination of the above methods is the best

Presence of either of the following states in the sample of grain is an indication of the presence of insects :

- Clustering of grains
- Decay or powder
- Foul smell
- Grain bag temperature higher than the ambient
- Presence of white spots on seed coat indicate the existence of eggs
- Larvae skin

Identification of the problem

In order to minimize the damage caused by insect infestation, a proper control measure strategy must be developed. Identification of the insect(s) involved is an important step in this direction. Different species of the insects behave differently and may not respond to one control measure in the same way. Identification of the species of the insect and its means of propagation is, therefore, helpful in devising a suitable control measure.

8.1 Insect control measures

Plan for control

- Assess the magnitude of the problem.
- Select control measure based on :
  - Potential risk of contamination
  - Physical facilities available
  - Risk to employees
  - Cost

The efforts to protect grain against insects can take two forms :

- A preventive effort before storage of the grain, from the time it is received, even if no insects are visible
- A curative effort during or even before storage, if necessary

In both cases, the insects must be destroyed without altering the food quality of the grain. But, to accomplish this, some general hygienic measures and steps for treatment of the premises must be observed.

Treatment of premises

Before any application of insecticide to storage buildings (warehouse, silo), the entire premises must be thoroughly cleaned. The range of available insecticide products is broad enough to treat different surfaces according to their characteristics. Different treatment should be given as follows :

- **Uneven surfaces (bricks, breeze-block, raw wood, *etc.*) :** Treat by spraying with powder mixed with water.

- **Smooth, non-porous surfaces (metal, polyester) :** Spraying with a stickier concentrate is preferred.
- **Ambient treatment :** It is designed to destroy flying insects by aerosols in hermetically sealed premises. This treatment should preferably be carried out in the evening, when flying insects are most active.

Types of control measures

Insect control measures can be any one or a combination of following methods :

- Physical and mechanical methods
- Chemical methods
- Sanitation
- Exclusion
- Integrated pest management

8.2 Physical and mechanical methods

Drying and disinfestation

Generally all agricultural commodities need to be dried to safe moisture level, below 11-12%, prior to storage. Crops are usually harvested at high moisture content to avoid shattering losses. Solar drying of legumes can be done on cemented platform, mat, jute cloth or metal sheets. If grain temperature is increased up to 60 ^{0}C and maintained for 10-15 minutes, all live stages of pulse beetle present in pulses are killed. Solar absorbance surfaces can effectively be used for disinfestations of pulse grains by raising the grain temperature.

Reducing inter-granular space

Adult pulse beetles, being very weak and having a short life, cannot move in grain mass and are restricted to top 15 cm layer. Even the adults emerging out of the infected material cannot move in the inter-granular space and could die before mating. The inter grain space varies according to size of different pulses. Movement of adult pulse beetle can be prevented by placing a 7-10 cm layer of dry sand at the top of grain mass. Dry activated clay can also be used for the purpose. To prevent mixing of sand or clay with the material, a paper or polythene sheet can be placed on the top of surface of pulse grain and then sand or clay is placed.

Coating with clay or oil

Small quantities of pulse produce are kept at farmers' level for consumption or seed purpose. The quantity ranges from 10-100 kg and kept in mud container. The pulse can be treated with clay @ 1-2% clay uniformly mixed with whole grains and kept in closed container. Vegetable oils can also be used to prevent pulse beetles. Non-drying oils, such as castor, niger, sesame *etc*., are preferred for the purpose. A dose of 0.5-1.0% is mixed with the whole grains to be stored. The insect stages already present before treatment, would survive. But application of oil will prevent laying of eggs and/or larvae hatching on grain surface and the insects would be killed before entry into the pulse. Neem oil has also been found effective @ 2-5 ml/kg to prevent insect activities.

Use of improved storage structures

Moisture proof, air tight, low cost and low thermal fluctuation structures have been designed as an improvement over old traditional structures. Some of such structures are Pusa bin, Pusa kothar, Pusa cubicle and improved bamboo basket. These structures were found effective for chickpea, lentil, pigeonpea and mungbean in humid and dry regions. The seed retained very high germination and insect damage was less than 1%. Use of these improved structures in keeping small bags as moisture proof facility has made them quite acceptable at farm level storage. Metal bins up to 1 tonne capacity are used for storage of seed legumes in dry regions. Bamboo basket pasted with mud and kept at high place also serves the purpose of pulse storage. Coaltar drums and biscuit tins can also be used with some modifications. The use of polythene lined bags to retain low moisture is found useful. For non-airtight structures, fumigation is often required which is usually not feasible under rural setup.

Air tight storage

C. maculatus and *C. chinensis* infested mungbean subjected to air tightness results into check in insect population build-up. Accumulation of carbon di-oxide and depletion of oxygen levels adversely affects the insect growth. Incorporation of *eucalyptus* and mint oil in airtight conditions results in quick arrest of infestation and ensure better protection in small quantity of legumes.

8.3 Chemical methods

Most of the physical methods suggested earlier may not give total insect control. Application of chemicals, therefore, sometimes becomes essential for complete insect mortality and prevention of insect growth. It features two broad types of treatment :

- Treatment by contact insecticide
- Treatment by fumigation

Treatment of grain with contact insecticide

This consists of covering the grain with a film of insecticide that acts on contact with insects, with effects that vary in rapidity and persistence. These products come in various forms (powders for dusting, powders to be mixed with water, liquid concentrates or fumigants) that dictate their techniques of application. For grain that is to be stored in bulk, the insecticide is incorporated directly into the grain by spraying before the silos are filled. For storage in bags, previously cleaned grain is mixed with powder or sprayed before bagging. In order to avoid re-infestation of grain stored in bags, further repeated dustings or sprayings are carried out while the bags are being stacked and during the storage period. The machinery used for dusting grain can range from the simple mechanical duster to motorized dusters, however, with this type of equipment, the grain is not treated uniformly, some areas receiving more dust than others. Spraying can be mechanical (pressure sprayer), pneumatic or thermal, and provides a better distribution of the product over the grain. In big storage centres, in order to obtain an even more regular distribution and a good coating of insecticide, the grain is fine-sprayed by a compressor equipped with a mist nozzle. Although contact systems of treatment are certainly effective on fully-developed insects, they have little or no effect on the eggs or larvae. Furthermore, some residues of the product, though not highly toxic, may linger in foodstuffs.

Treatment of grain by fumigation

Fumigation is a treatment that rids stored grain of insects by means of a poisonous gas called a fumigant. This substance, produced and concentrated as a gas, is lethal for specific living species. Unlike contact powders, the fumigant penetrates to the interior of the grain mass and reaches the largely invisible incipient forms (eggs, larvae) developing there. Fumigants spread throughout the area where released, therefore, used in totally sealed enclosure. Thus, when grain stored in bulk is fumigated, the bins must be perfectly airtight. For grain stored in bags, the usual method is to cover the bags with a tarpaulin whose edges are sealed to the ground or the walls. The effectiveness of fumigation depends, on the one hand, on the actual concentration of the gas and, on the other, on the length of time during which the grain is fumigated.

Which fumigants to use?

Generally two types of fumigants are available for fumigation purposes in grain storage programme.

1. **Methyl bromide :** It has a quick action and the grains can be aerated after 12-24 hours of its application. However, it is highly toxic, colourless and odourless, has residual effect in the grain and accumulates in the human body. For this reason, methyl bromide should not be used as a fumigant in grain storage programme.
2. **Magnesium or Aluminium phosphide :** Gas released from this chemical is known as Phosphine. This fumigant has a small molecular weight (34.04) and thereby has excellent penetration capacity. The weight of phosphine gas is similar to that of air, so it easily gets mixed with air and spreads all along the stored grains. This eliminates the need to have re-circulating fans to circulate the air. This is very effective against most pests but does affect taste or smell of the

fumigated grain. At the same time, it leaves no residues on the grain, so it can safely be used for food grains.

Moreover it does not affect the germinability of seeds and therefore, can safely be used for storage of seeds also. However, it is inflammable at normal temperature, so proper care should be taken at the time of its application. This has a delayed release and, therefore, requires longer period of fumigation than other fumigants.

Depending on weather methyl bromide or phosphine is used, the duration of fumigation should be 24-48 hours for methyl bromide, or a minimum of five days for phosphine. The latter product is more commonly used, since its application, in the form of pellets spread throughout the grain mass, is simpler. It is essential to recognize, however, that fumigants are very poisonous to people and therefore the staff that is to use them must be carefully trained in their application. For all these treatments, it is important to scrupulously observe the recommended protective and safety measures (masks, gloves, hand-washing, hermetic sealing of phosphine containers, etc.).

Conditions for application of phostoxin

Remember that these treatments are curative, and have no persistence over time, therefore, a combination of the techniques of contact insecticide and fumigation is recommended.

Location : Any space that can be enclosed and made air-tight can be used for fumigation of grains.

Temperature : The duration of fumigation treatment is highly dependent on ambient temperature condition. Higher is the temperature, more effective is the treatment. Some important guidelines are as follows :

Temperature range, °C	Fumigation period
20 and above	4-5 days of exposure
16-20	6 days of exposure
11-15	8 days of exposure
05-10	10 days of exposure
Below 5	Do not fumigate

Relative Humidity : Humidity of the ambient air influences the rate of release of phosphine gas. Higher the RH, higher is the rate of release of gas. There is no release of gas below 30% RH. Under this condition, water containers should be placed below the fumigation sheet.

Right concentration : It is essential to maintain the required concentration of fumigant in the sealed space and for sufficient time in order to have effective control of all stages of the pest. The fumigation sheet, therefore, should be air-tight and properly sealed with the floor with the help of paper tape. The floor should preferably be of concrete.

Proper hygiene : Fumigants are not persistent and therefore, the possibility of re-infestation should be avoided. This can be done with carrying out surface treatment of the storage area with Malathion. This has a volatile action and is effective against flying insects.

Some do's and don'ts

After fumigation, the grain storage should be aerated and thoroughly cleaned. The collected trash should be removed away from the storage area to prevent further breeding of insects and re-infesting the grains.

Before carrying out fumigation operation, it is important to know how to detect and measure the concentration of released gas in the air and the precautions to be taken to avoid hazards.

Do's :

- Fumigants should be kept safely and outside the reach of ordinary persons. Only trained persons should carry out the fumigation work.
- Use a gas mask with the correct filter.
- Wash and preferably take bath after fumigation.
- Use a display board indicating the fumigant being used, date of application and person in charge.
- Do keep gas monitoring device to determine the gas concentration during fumigation.
- Aerate after uncovering.
- Fumigation should be carried out away from office/residential areas.
- Collect the residues after fumigation and throw in water. Bury the used containers.
- Keep first aid treatment box handy to deal with accidental exposures to the fumigants.

Don'ts :

- Never work alone.
- Do not eat, drink or smoke during or immediately after fumigation.

Limiting values of fumigants

Gas concentration in the air which is safe for human being is known as threshold limit value of the fumigant. Threshold limit values of the two commonly used fumigants are :

Properties	Phosphine	Methyl bromide
Threshold limit value	0.3 ppm	5 ppm
Odour threshold value	1 ppm	0 ppm
Skin absorption	Negligible	Slight
Chronic effects	Not known	Affects nervous system

8.4 Rodents and their control

Rodents and types of damage

The second most important pest in pulse storage is rodents. Rodents invade and multiply in or near storage places, where food is available in abundance. It causes serious damage not only to stored products but also to packaging and even to storage buildings. The principal rodents, those most common and likely to attack stored products, belong to the following species :

- Black rat, also called roof rat (*Rattus rattus*)
- Brown or Norway rat, also called sewer rat (*Rattus norvegicus*)
- Mouse (*Mus musculus*)

Rodents not only feed on the grains but also contaminate more than 20% what consumed with their faeces, urine and hair. Prolonged attacks by these pests inevitably results in serious quantitative losses, up to 3-4%, of stored products. These losses must be added to those arising from the decrease in quality of the foodstuffs, caused by the filth (excrement, secretions) rodents leave behind in the stored products. This contamination is as important from the marketing standpoint as it is for hygiene and health. Indeed, rodents are often the vectors of a number of serious diseases like rabies, leptospirosis *etc.*

Control measures

Rodent control is a difficult task. Simple measures cannot be adopted for rodent control. A combination of following measures often becomes essential :

- **Sanitation :** Keeping the storage and surrounding area clean
- **Exclusion :** Keeping them out
- **Killing :** Killing those that get in

Sanitation

Sanitation, both outside and inside the storage structures and processing plants, helps in proper control of rodents.

Outside and surrounding areas should be kept clean so that rodents do not find shelter near the storage area. The following measures should be taken :

- Keep bushes/weeds cut and grass well mowed.

- Make pavement around the building for 1-2 meters to reduce cover. This will help prevent rats digging under the building.
- Keep the entire area well drained. Care should be taken not to have any garbage bins near the building.
- Discarded equipment and boxes should not be dumped around the building.
- Do not have a garbage dump near the storage area.

Inside area of the building should be kept clean. This creates distraction for the rats to stay inside the building. Some suggested measures are :

- Walls and floors of the storage should be smooth. This helps in easy cleaning. Walls and corners should be kept free of dust, trash and spider webs.
- All the wastes products, dust *etc.,* should be removed immediately after any operation.
- Bags should be stacked on pallets and not directly on floor. This helps in reducing hiding cover for the rats.
- A minimum of 75 cm distance should be kept in between wall and stacks. This helps in easy movement of workers and also reduces cover for rats.
- Walls should be painted with light colour. This reduces dark corners where rats prefer to stay.

Exclusion

It is an important idea to prevent the rats and birds from entering inside the storage area. Although it is a difficult task yet constructing rat-proof building and then careful operations greatly helps in controlling the entry of rats into building. Some suggested measures are :

- The outer wall of the building should be of a material that rats cannot chew and should be smooth.
- A 25 cm wide rat shield should be installed at a height of 1-1.5 m all around the building. This helps in preventing the entry of rats.
- Floor of the building should be constructed at the height of truck bed height.
- Doors and window frames should be of steel and properly fixed with wall avoiding any gap between frame and wall.
- Windows should be screened with metal mesh to keep out flying insects.
- Lower 20 cm of tightly fitted doors should be covered with metal sheet lining.

- Doors should not be left open when not in use.
- Doors which are required to be left open for longer durations should be provided with transparent plastic panels to prevent entry of birds.
- Provide proper cement plaster slopes below the windows to prevent birds from making nests.
- Ensure that no board or bags *etc*. are kept outside the building touching the wall otherwise rats can jump over the rat shield and make entry into the building.

Killing

Rats that get inside the building must be killed immediately. Different methods can be used to kill the rats.

- Field rats live in burrows. To kill these rats, one zinc phosphide tablet per burrow is required and mouth of burrows need to be sealed with mud after placement of the tablets.
- Rodents in storage premises are controlled using physical, chemical and mechanical means.
- Various kinds of rat traps can also be used to catch the rats.
- Chemical method of rat control involves poison baiting to kill rats. Zinc phosphide in food bait or ready to use single dose anti coagulant can be used for poisoning rats. Other chemicals for the purpose are barium carbonate, red squill and ANTU. Baits with slow-killing and anti-coagulant poisons are accepted by rats better than fast-killing poisons. Initially baits should be offered without poison to lure the rats to the feeding place.
- Poisoned water and feeders should be kept at strategic places inside the building. In such cases, no other water should be allowed inside the building.
- Sonic and ultrasonic repellents are also being used to repel rats.

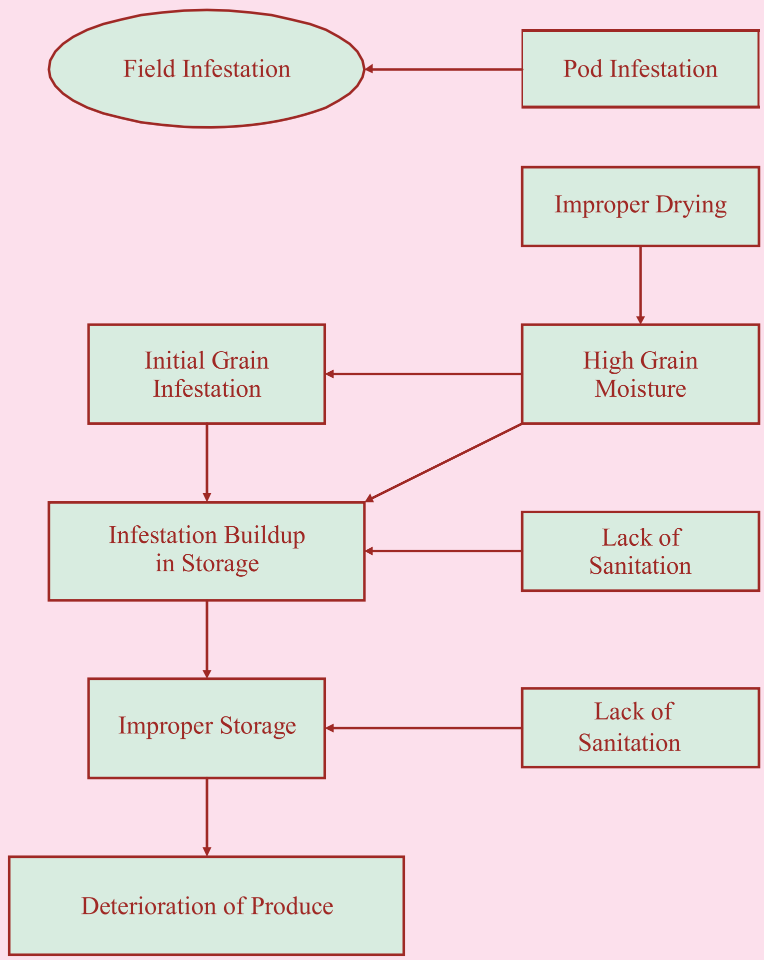
8.5 Integrated management of bruchids

Why integrated management of bruchids ?

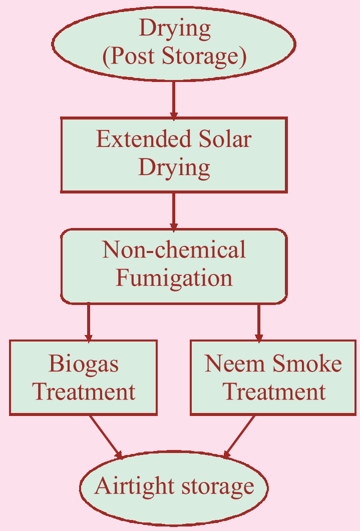
To control the bruchid infestation during storage, it is essential to understand the factors, which promote the insect growth. Usually the infestation starts from the field itself and is carried to store houses. In order to kill these insects at various stages of growth, sun drying is the most common and preferred method. Proper drying not only kills the insects, germs and fungi, but also reduces grain moisture to the limits of safe storage. Lack of sanitation and improper storage creates environment conducive for re-infestation. This ultimately results into deterioration in quality of stored produce. Researchers have developed several strategies to control or eliminate field infestation before storing the grains followed by preventive measures to check cross infestation. Since bruchids, like other stored grain pests, increase ten folds with each generation, controlling bruchids at early stage is a must. If delayed, considerable damage could take place, making grain unfit for human consumption.

IPM strategies against pulse beetle

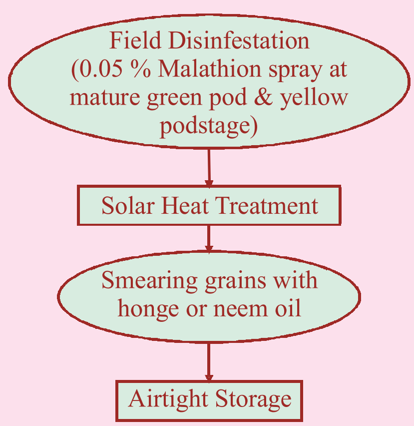
Following flow charts depict the infestation process and few IPM strategies :



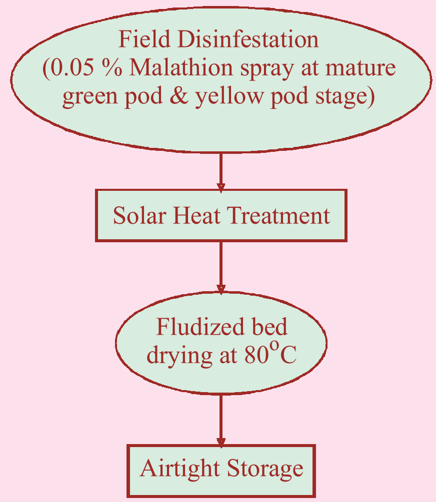
Stored Grain Infestation Process



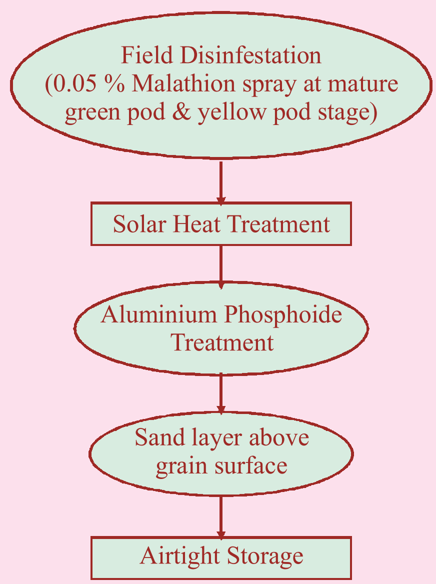
Integrated Control Strategy - I



Integrated Control Strategy - II



Integrated Control Strategy - III



Integrated Control Strategy - IV

9. Milling of Pulses

What is milling?

Pulses are mostly consumed in the form of dehusked splits, commonly known as *dal.* The outer layer of the grain (husk) is attached to the protein and starch bearing cotyledons of the pulse grains. In some grains like pigeonpea, mungbean and urdbean, this bonding is strong due to the presence of a layer of gums in between the husk and the cotyledons. These are known as difficult-to-mill pulses. In other grains like chickpea, pea, lathyrus *etc.,* this bonding is comparatively weaker. Such grains can be milled easily and are categorized as easy-to-mill pulses. This outer husk layer is required to be separated from the cotyledons and subsequently split in two halves before consumed as *dal*. The process of removal of husk from the cotyledons is called dehusking and the entire process of dehusking and subsequent splitting of cotyledons, its cleaning, polishing and grading is known as milling. Dehusking improves product appearance, texture, product quality, palatability and digestibility. A substantial amount of avoidable loss takes place at different stages of milling. This may vary from 10-15% depending upon the type and quality of grain milled, the process and machinery used for milling and other factors. It is, therefore, important to look at different aspects of milling so that proper process and machinery are used to obtain maximum recovery of good quality *dal* from the grain and take corrective measures to reduce milling losses to the minimum.

Pulse milling is the third largest food processing industry after rice and flour milling. There are about 15,000 mills scattered all over the country. An estimated 75% of pulses produced are processed for making *dal* in mills of different capacities.

Milling of pulses involves two major steps: (i) loosening of husk and (ii) removal of husk and splitting into cotyledons with the help of suitable machine. All kinds of pulses require some pre-milling treatment for ease of husk removal. However, processes and equipments for loosening of husk, separation of husk from cotyledons and its splitting differ from crop to crop, cultivar to cultivar and place to place. Dehusking is an age-old practice, which originated at home and later developed into a cottage industry and now has grown into a large-scale organized industry.

Home scale milling

This involves pounding of grains for dehusking by using a mortar and pestle after mixing with small quantity of water and drying in the sun for a few hours. Sun-drying after water application helps to loosen the husk from the cotyledons. In mortars, dehusking is achieved due to shearing action between pestle and grains, and abrasive effect between the grains. Once the pounding is done for several minutes, the husk gets detached from the grains. Winnowing separates husk and split cotyledons are separated from the whole dehusked and unhusked grains by manual sieving. The whole grains are again pounded for further dehusking and splitting. This technique of dehusking is generally adopted when small quantity *i.e.,* up to 5 kg of pulses is to be dehusked. *Dal* yield by this process is quite low (50-60%) due to breakage and chipping of the edges of cotyledons.

Cottage scale milling

Traditionally, villagers use the hand operated wooden or stone *chakki*/ sheller when comparatively large quantities of pulses are to be dehusked. The technique is similar to those of the home-scale methods. The pre-conditioning of grains before milling is done either by prolonged sun drying until the hulls are loosened or through application of water followed by several hours of sun drying and tempering. The heating of the grains in pan with or without sand along with vigorous stirring is also in practice. The duration of treatment depends upon the variety of pulses to be milled. There are no standard dehusking techniques at the cottage level. Different combinations of methods, depending upon the experience and available facilities, are followed. Of late, mechanized shellers and plate mills are used for custom milling of preconditioned pulses. At cottage level milling, often the husk is not completely removed and breakage is also quite high. This reduces the consumer appeal and value of the product. The yield of head *dal* obtained from these techniques may very in the range of 55-70% depending upon the variety of pulse and pre-treatment used.

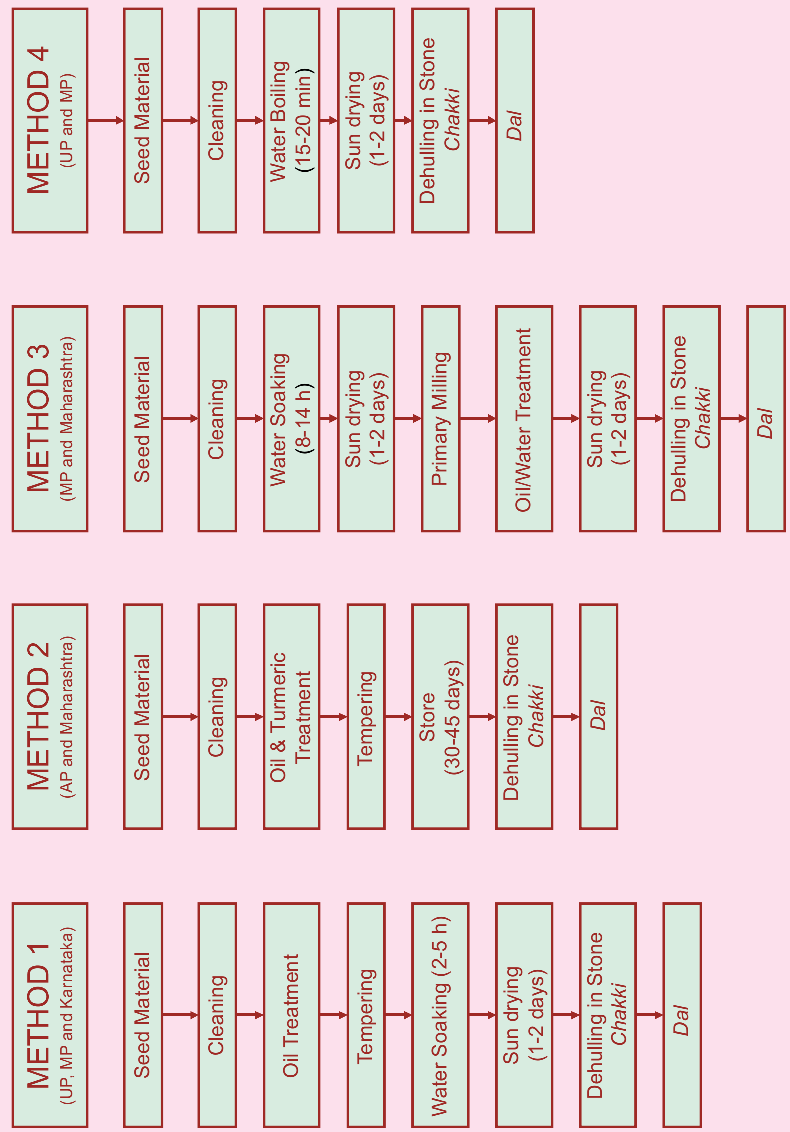
Commercial scale milling

Commercial scale milling involves processing large quantities of pulses in plants of bigger capacities. Even though, the basic milling procedure is similar, specifics of dehusking methods vary widely from one *dal* mill to another *dal* mill and region to region. Two methods for large scale processing or pulses are in practice. Traditional method, most commonly followed by *dal* millers, is almost similar to cottage level treatment in principles. A modern method of milling has been developed at CFTRI which is independent of weather conditions.

Traditional milling

It has already been said that the milling process varies from mill to mill and region to region and no standard or common process is in practice. The sequence of operations like pre-milling treatment, conditioning, dehusking, and splitting is normally common. Large variation exists in the steps followed in milling but basic unit operations remain the same.

Traditional methods of dehulling pigeonpea followed in various Indian states



9.1 Milling process

Essentially milling process involves cleaning, grading, pitting, treatment milling and polishing operations. Usually milling processes are described for the toughest to mill pulse grains *i.e.,* pigeonpea. The major steps involve in pulse milling are discussed below :

Cleaning and grading

It involves removing dust, dirt, foreign material, off sized, immature and damaged grains and grading in two or more fractions to process separately.

Pitting

Use of emery-coated roller is a common practice in commercial *dal* mills. The emery coating is used for abrasive or refractory action. Whole pulses are passed through abrasive roller machine for scratching of seed to facilitate the entry of oil/water in the grain during pre-milling treatment.

Pre-milling treatments

The treatment is given for loosening of husk from cotyledons, which is attached through a gum layer is called pre-milling treatment. Mostly pre-milling treatments are developed for pigeonpea. Water soaking, oil and water application, mixing of sodium bi-carbonate solution and thermal applications are commonly recommended and adopted pre-milling treatments. For commercial milling in large capacity *dal* mills, oil and water treatment is commonly adopted, whereas for household milling, water treatment is popularly used.

Different methods are employed in different regions depending upon type of grain. This also varies from mill to mill. Pre-treatments can be broadly classified into i) wet treatment and ii) dry treatment.

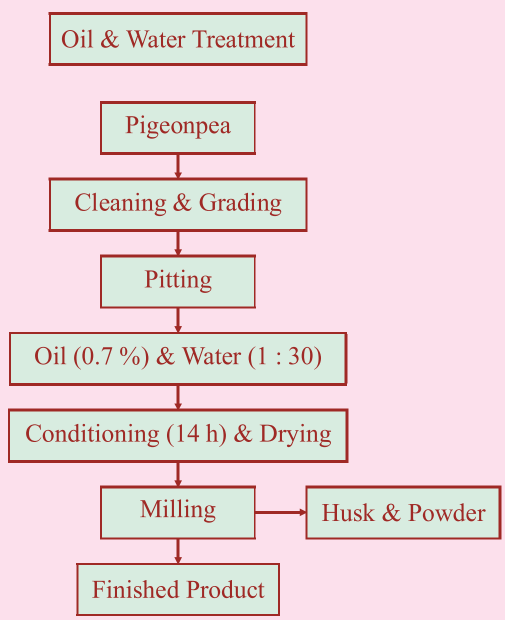
Wet treatment

In this method of treatment, soaking and drying are considered as effective technique to loosen the husk. This method has the advantage of facilitating dehusking and splitting the cotyledons, giving less breakage. This can be attributed to lower deshusking percentage of grains in water treatment process. However, it has the disadvantage of being weather dependent and labour intensive. *Dal* produced by this method cooks better but takes longer time to cook. Commonly adopted red earth treatment is considered as wet method. In this method, grains are thoroughly mixed with a paste of red earth after soaking in water for about 12 hours and heaping for about 16 hours. The grains are spread in thin layer in drying yards for 2-4 days. When dried, the red earth is removed by sieving and the grains are then milled on power operated stone or emery coated vertical *chakki* to yield *dal*.

Dry treatment

Dry milling treatment is reported to produce *dal* that cooks faster, however, losses due to broken and powdering are high. In dry method, oil/water application followed by drying are important steps in processing of pulses.

Wet treatment



Dry treatment

In this process, after cleaning and grading, grains are pitted and then mixed with about 1% oil (linseed), thoroughly and spread for sun drying in thin layer, for 2-3 days. At the end of drying, 2-5% of water is sprayed, mixed thoroughly and tempered for overnight. Tempered grains are dehusked in roller machines to give dehusked grains and *dal*.

Tempering

Once the pre-milling treatment is given, conditioning is done to have uniformity of treatment throughout the grain mass. This process gives time for better penetration of oil/water beneath the seed coat to dissolve gums.

Drying

In most of the mills in India, sun drying method is commonly practiced. Grains are spread in thin layer on *pucca* floor under the sun and stirred frequently with rake/feet for even drying. This operation makes process of *dal* milling a very lengthy requiring (2-3 days). In this case, sun-dried grains require more passes and consumes more energy. The drying time with the use of dryers ranges between 2-3 hrs, which results in tremendous time saving. Dryers are used in few mills that too in rainy seasons for drying of treated grains.

Dehusking and splitting

Dal mills by and large use emery rollers for dehusking and splitting. In case of pigeonpea, more than 3 passes are required for complete milling. Other pulses take one or two passes in emery mill in order to achieve maximum milling. The physical, chemical and structural strength of grain coupled with the functional and mechanical characteristics of processing units jointly play an important role. Grain properties such as hardness, load deformation behaviour, shape, size density and variety of grain *etc.* have considerable effect on *dal* yield. The machine parameters such as roller speed, clearance, emery size *etc.* have vital role to play on *dal* recovery. As a result of milling, unhusked and dehusked whole grains, split cotyledons, broken, husk and powder are obtained. Whole grains are passed again for further dehusking and/or splitting after water treatment. Husk and powder produced during milling is generally separated with the help of aspirator and are used as cattle feed.

Polishing

Polishing is done to increase consumers appeal and is a form of value addition, though not desirable. *Dal* is polished in different ways, such as nylon polish, oil/water polish, leather and *makhmal* polish. Generally polishing is done using soap stone, oil or water. Polishing gives uniform look and shine to each grain.

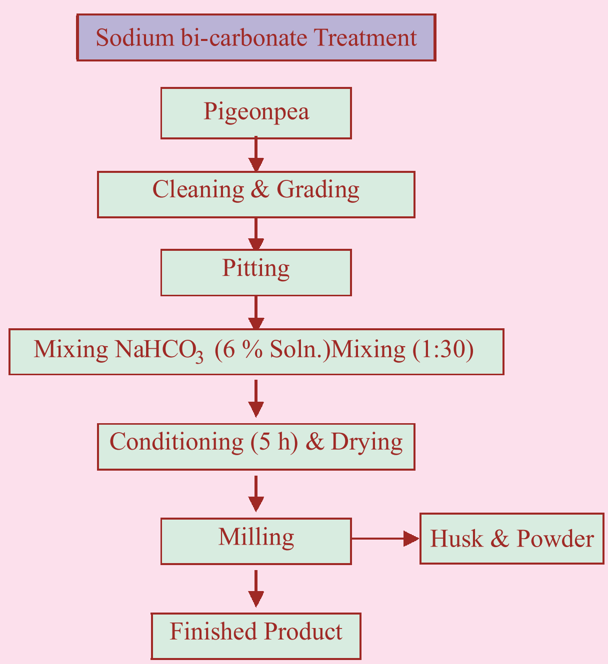
9.2 Advances in Milling Technology

As pigeonpea grains are most difficult-to-mill, most of the researches about pre-milling treatments and pulse milling were confined to pigeonpea only. Until recently, few pre-milling treatments *viz*., heat, chemical, enzyme *etc*., were tried at various research organizations for milling of pigeonpea. However, oil and water treatment is most prevalent in modern *dal* mills. Water soaking followed by sun drying is commonly adopted at rural level pigeonpea processing.

Traditionally water/oil treatments are given for loosening of husk. These traditional pre-milling techniques are labour intensive, wasteful and weather dependent. Attempts have been made by various Research and Development institutions to develop improved processes for pre-treatment of pigeonpea in order to achieve efficient and economic milling of pulses. Research outcome of different organizations conducted on pigeonpea grain are as under :

Pantnagar process (Chemical treatment)

In this method, cleaned and graded pigeonpea grains are treated with 10 per cent sodium bicarbonate solution mixed in the ratio of 30:1. These grains are then heaped for 5 hours at 30 ^{0}C followed by drying under the



Pantnagar process

sun. The tempered and dried grains are passed through rollers. Pantnager process utilizes traditional milling machinery. The milled product is cleaned and graded with a blower, cyclone separator and grader. It is claimed that if pre-milling treatment is properly given, 91-95% dehusking is achieved in single pass having 4-5% whole grain. The husk, broken and powder are removed separately. The *gota* (dehusked whole grain) obtained is mixed with 2-2.5% water and kept for 4 hours for tempering. These grains are passed through splitter for *dal* making. It has also been observed during the tests conducted that 80-90% of total sodium content is removed with husk and powder. Whereas the remaining traces of sodium in *dal* improves its cooking quality and storage characteristics. The *dal* recovery has been claimed as 80%. Advantage of this method is that it eliminates the use of oil. But the problem with this method is that the chemical solution goes with the husk and this may be harmful to cattles, if used as cattle feed.

Pantnagar process (Enzymatic treatment)

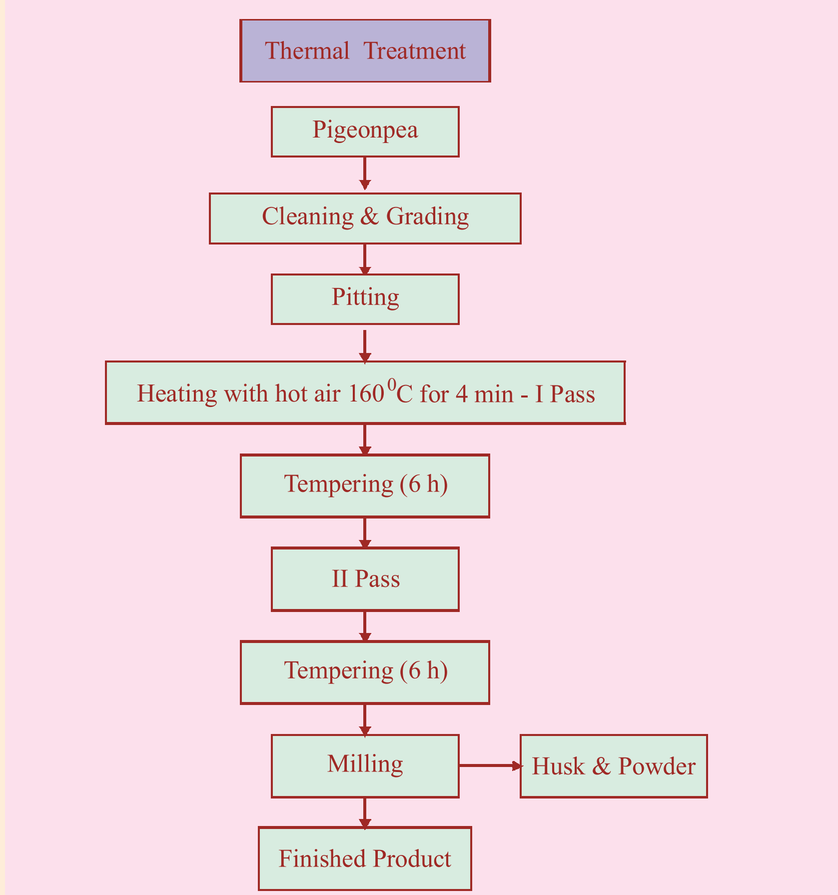
At Pantnagar, milling experiments were conducted on enzyme treated pigeonpea grains at different combination of pre-treatment parameters such as moisture content of seed, incubation period and temperature. The results obtained indicated that enzymatic pre-treatment has positive effect on hulling efficiency. Hulling efficiency of untreated grains was found to be 60.82%, while the same for enzyme and water treated grains was achieved at 89.68 and 73.90%, respectively. It has been pointed out that high amount of powder formation during dehusking of pigeonpea have sizeable impact on its availability. The enzyme treatment not only increases the hulling efficiency but also reduces the amount of powder formed. The effect of enzyme concentration on hulling efficiency was also studied. Besides, it has also been claimed that enzyme treatment improves digestibility of *dal* protein and reduces cooking time.

CIAE process

Cleaned and graded pigeonpea grains are fed in a roller mill for scratching. The clearance between the outer screen cage and inner abrasive roller is fixed and maintained throughout the process. Once the scratching is over, then grains are cleaned to separate the husk and split grains. Whole and split grains are soaked in water at ambient temperature for 25-30 minutes to produce moisture content of about 35 (%, w.b.) and then dried to 10% moisture content. The dried grains are milled in a cylindrical abrasive mill to produce dehusked split *dal*, which is separated from other constituents with an air-screen grain cleaner. The average recovery for pigeonpea is claimed to be 75%. This method eliminates the use of edible oil in the milling process.

CFTRI process

The technology developed at CFTRI overcomes the major problems of weather dependent nature of pulse milling industry and gives high *dal* yield in lesser time. The process is independent of weather conditions and eliminates the use of oil. The loosening of husk is achieved by heating of grains in hot air current followed by tempering. Removal of husk and splitting of grains is achieved by improved processing machines. This conditioning technique through heat treatment and moisture adjustment of the cleaned, size-graded grains loosens the husk, while making it fragile and brittle besides hardening the kernels. The process involves two passes in a drier with 160 ^{0}C hot air, followed by tempering for 6 hours. The operation is continuous, replaces sun drying and carried out indoors. It is claimed that this method gives average yield of 80% *dal*. Many *dal* millers have not adopted this technique due to high electrical energy consumption, non-



CFTRI process

availability of sufficient and continuous supply of electricity, high cost of machinery, and non-utilization of traditional milling machinery. However this method has definite advantages like less requirement of manpower, no need of drying yard, no requirement of edible oil *etc.,* which demands due considerations.

9.3 Milling of Individual Pulses

Depending upon ease of milling, pulses are categorized in easy and difficult to mill pulses. Presence of gum layer in between seed coat and cotyledon, its quality and quantity plays an important role in dehusking process. Lentil, chickpea and peas come under easy-to-mill category, whereas pigeonpea, mungbean and urdbean fall under difficult-to-mill pulse crops. Gums and mucilage present beneath the seed coat cause adherence of seed coat with the cotyledons. Pigeonpea is considered to be the toughest-to-mill among all pulse crops. Certain pulses like pigeonpea, urdbean, mungbean, and horsegram pose great difficulty in dehusking, while pulses like chickpea, peas, lentil and *khesari* are relatively easy to dehusk. This difference in dehusking behaviour can be attributed to the characteristic of husk that adheres the cotyledons so tightly that poses difficulty in its removal during milling. Higher degree of attachment causes heavy milling loss in the form of broken and powder. Therefore, loosening of husk prior to milling through various treatments is an essential prerequisite.

Pigeonpea

This is the most difficult kind of pulse to mill because of tight attachment of husk to the seed coat. The clean and graded grains are pitted (scratched over the seed surface), oil smeared (0.2-0.5%), tempered for ½ to 1 day in bins, treated with water (in the ratio 1:20-25), stored over night and sundried for 2-3 days before passing through the emery roll. Such type of husk loosening and dehusking operations are repeated 2-4 times till more than 90% grains are dehusked. *Dal* obtained during this method is termed as Grade-II *dal* as edges of most of the *dal* gets rounded off during milling. The mixture of dehusked and unhusked whole grain is further sprinkled with water and tempered for few hours, sundried and splitted in horizontal or vertical *chakkies* or by using *patka* machine. The *dal* thus obtained is considered as Grade-I *dal* since it has no chipped edges *dal* and has better customer acceptability. The recovery of pigeonpea varies from 68-75%, depending upon variety milled and method followed.

Chickpea

It falls in easy-to-mill category of pulse. Dehusking after cleaning and grading can be done in roller mills. Splitting of '*gota*' (dehusked whole grain) is carried out by treating the grain with water in ratio 1: 2.5 to 3.0, followed by tempering for 12 hours and splitting in disk sheller. This does not require oil application for loosening of husk. The process is repeated till all the grains are dehusked. Recovery from *dal* varies from 78-82%. *Chana dal* and broken can further be processed to produce *besan*. At household level, the burr mill is used to obtain *besan*. Hammer mills, which beat the *dal* to the particle size till it passes through the sieve of desired particle size, are employed at cottage and large scale for *besan* making. The recovery from these *besan* plants is 98% and only 2% of *dal* is lost due to burning and are lost in form of unrecoverable dust.

Urdbean

The process involves cleaning, grading and pitting in emery roller mills. Two or three passes will be required to complete dehusking and pitting operation. Husk and powder produced in each pass must be removed after every pass. About 0.5% oil is applied to the pitted grains, which are then stored for 12 hours. The grains are then sundried for about 2-3 days followed by water spraying in the ratio of 1:25-30 and tempered overnight. These grains are passed through rollers for dehusking. The *dal* splits obtained is called Grade-II *dal*. The '*gota*' obtained is passed through burr mill to make Grade-I quality *dal*. To give luster and enhance market value, *dals* are polished using soapstone powder.

Mungbean

It is difficult-to-mill because husk have the high degree of adherence to cotyledons. Husk is thin, soft and slippery in texture. Bond between the two cotyledons is weak, therefore, splitting occurs prior to dehusking. In order to achieve proper dehusking of mungbean grains, oil treatment is applied. Pitting, oil smearing and sun drying are followed by dehusking and splitting in roller machines. The loss in form of broken and powder is large in case of mungbean due to its thin seed coat and rubbing operation during dehusking.

Peas

This is easy to dehusk. The whole grains of peas are sold as such in the market generally after polishing to enhance the customer appeal. However, its *dal* is consumed in some parts of the country. The milling process includes cleaning, grading, moisture application, tempering and sun drying up to the milling moisture content (10-12%, d.b.). Dehusking and splitting can be achieved in roller mills or disk sheller. Recovery *dal* from peas ranges from 80-82%.

Lentil and Khesari

Both of these pulses falls in category of easy-to-mill type of pulses. The practice usually applied involves moisture addition after cleaning and grading process, followed by tempering and sun drying. Dehusking and splitting is carried out in roller machines. Dehusking process is repeated till all grains are split and dehusked.

10. Machineries Used in Processing of Pulses

The major part of pulse produced in India is converted into *dal*. Many products are made from whole or dehusked pulses. Roasted pulses, pulse flour, *'sattu'*, sprouts, fermented products *etc*., are quite commonly produced at domestic and commercial level to cater the requirement of consumers. For most of the pulse based products, dehusking is an essential operation. It improves textural and culinary properties of the grain. Over 15,000 *dal* mills are located in different part of the country. But still the manufacturing of *dal* milling machineries is not an organized industry. Normally, the mills are fabricated by local artisans, who fabricate the machine at the site as per available space and process requirement of individual *dal* miller. Power requirement, capacity, operating parameters and machine specifications vary from place to place and artisan to artisan. However, these artisans work on the basis of their personal experiences and mostly depend on trial and error approach, which often results into poor *dal* yield with high energy loss.

Conventionally, in northern India, two or more storied buildings are used for milling of pulses. Higher structure reduces the space requirement but requires more power as grain has to move vertically with the help of elevators. These multi-storied mills are commonly called as 'Agra Type'. In southern India, single storied structure is preferred for pulse milling. Such mills are popularly known as 'Hyderabad Type'. Commonly used machineries in *dal* milling plants for different unit operations are :

Cleaning and grading

Raw pulses need to be cleaned before milling. Normally rotary or reciprocating screen cleaners are used. Rotary screen graders are common in northern part of the country, whereas in the southern part, reciprocating screen graders are used. These graders separate the grains into different fractions based on size. Light impurities are removed with the help of blower or suction fans. Rotary screen cleaner/grader mainly consists of four compartments fitted with screens in sequence of increasing opening size. Smallest grains falls at the first compartment, whereas the largest one falls in the last column. Slope is given towards the direction of grain flow for ease of grain movement. Low RPM around 18-30, is maintained to ensure proper grading of raw material. Mild steel or wooden body is used to house these compartments depending upon choice of the customer. Reciprocating flat screen grader usually consists of three screens to separate the grain fractions. Blower is provided to remove dust, dirt and other fine impurities. Stroke length of 4-5 cm is provided for the reciprocating unit.

Dehusking

Typically carborundum/emery coated rollers are used for dehusking of different pulses. Cylindrical or taper rollers are used for the purpose. The foundation of taper rolls is kept horizontal whereas cylindrical rolls are mounted with inclination to the horizontal. This system facilitates ease of grain movement inside the drum. Normally, a slope of 15 cm for entire length of machine is recommended. Body of the roller is made of wood or steel on which mixture of carborundum/emery, chemical cement and salts are applied in layer of uniform thickness. The granule size of emery varies for crop to crop and type of operation to be performed on the grain. Recommended grades of emery are tabulated as below :

Crop	Operation		
	Dehusking/Pitting	Splitting	Polishing
Pigeonpea	16	24	---
Mungbean	24	30	35-40
Urdbean	24	30	35-40
Chickpea	---	24	---

The inlet and outlet of the roller can be adjusted for regulation of flow and retention time. These rollers are available in different sizes depending on power requirement, capacity, roller size and speed varies with every manufacturer.

Oil/Water applications

This machine is used for mixing of oil/water to the pitted pulses. Screw conveyors with full flight or cut screw are used. The screw slowly moves the grain forward, with the oil/water application at the entry of the conveyor. The grain gets thoroughly mixed with oil/water while traveling the mixer length. Cut screw flights, commonly used in southern India, also serve the purpose of agitator and increases retention time for better mixing.

Drying

Generally, sun drying on roof top or in open drying yard is practiced. Since sun drying is a weather dependent process, the operation of the mill stops during rainy and cloudy seasons. To make conventional milling plants operational round the year, artificial or mechanical drying is essential. Accordingly, various manufacturers developed some batch or continuous dryers for use in *dal* mills. In order to avoid sun drying, CFTRI, Mysore has developed thermal treatment process using dryers.

Splitting

To split the dehusked pulses and pulse seeds, roller mills, under runner disk sheller, attrition mill (*Chakki*), elevator and hard surface and impact sheller are used. Roller machines are similar to dehusking units, with emery roll made of medium size (24-30 No.) granules. Under disk runner machine consists of two horizontal disks with 1.25 cm emery coating. One of the disks is fixed whereas other one rotates. This rubbing action causes splitting of dehusked whole (*i.e.*, *Gota*). It can also be used for splitting of urdbean, chickpea, lentil, mungbean and soybean. The capacity of the machine depends upon size and speed of the disk. Attrition mills are vertical or horizontal stone or emery disks. Some millers to minimize breakage during splitting use elevator and hard surface combination. Dehusked splits are dropped from a height of about 3-5 m on a hard surface to obtain splits. Impact splitter machine consists of mild steel blades mounted on shaft inside an enclosed casing. Rotating blades throw the '*gota*' on stationary hard casing splits. The '*gota*' is split by impact in the machine.

Dal grading and _gota_ separation

'*Gota*' separation from milled fractions is a big challenge. Whenever the grain is passed through emery roll, some part of grain is converted into dehusked whole called '*Gota*'. It is difficult to separate dehusked whole grain from almost similar size whole grain using normal size grading machines. '*Gota*' separating machine, based on surface properties was developed by CFTRI, Mysore. Combination of rotary and reciprocating screens are used in modern pulse milling plants to separate '*gota*'. This machine is used for separation of '*gota*' and whole grains, splits and broken.

Polishing

Dal polishing denotes to removal of powder from dehusked splits and application of oil and water to impart shine and luster to the finished *dal*. Cylindrical hard rubber roll, leather belts or emery cone polisher is used for the purpose. Rollers mounted with brushes can also be used to impart shining to the *dal*. Powder particles are removed by rubbing action. Battery of screw conveyors with mild abrasive surfaces, like nylon rope or velvet cloth, can also be used for repeated rubbing. Accordingly they are named as nylon or velvet polisher. Depending upon level of polishing 2, 3, 4 or 5 screw conveyors can be used. Oil and water polisher is similar to the oil/ water treating machine. Water or oil is applied at the entrance of the unit, worm inside the mixing unit acts as a polisher, often *dal* is required to be dried prior to final packaging.

Powder and husk separation

Husk and powder is separated from dehusked pulses, using suction fan or blower. This unit may end into a cyclone separator and collected in bags, in order to reduce environmental hazard of fine dust in the plant premises.

Material handling

Bucket elevators are widely used in *dal* mills for vertical grain movement. Usually drying of grains takes place on the roof. This saves time and energy lost in material handling. In large capacity plants, bucket elevators often control feeding inside the mill.

11. Mini *Dal* Mills

Efforts have been made to develop improved methods and machinery to process pulses more efficiently and economically at various Research and Development institutions in the country. Notable among them are IARI New Delhi, CIAE Bhopal, PKV Akola, GBPUA&T Pantnagar, CFTRI Mysore, IIPR Kanpur *etc*.

However, some private entrepreneurs and State Agro Industries have also come up with certain milling machineries but they have localized presence and performance has not been properly documented. Mostly they have been developed by slightly modifying the traditional milling machine or the designs developed at R&D institutions. The salient features of these machineries are presented in the following paragraphs :

IARI dehusking cum splitting machine

It is a small capacity, low cost and portable type of machine. It consists of a cylinder concave set, a feed hopper and or blower. All these parts are mounted on angle-iron frame. The clearance between the cylinder and the concave is adjustable. A blower with duct is also provided with the machine, which facilitates separation of hull from the mixture of *dal* unhusked pulse and husk. The machine is run with the help of 1hp, 3-phase electric motor. The husk is removed due to rubbing of grains between the moving rough surface of the cylinder and the stationary rough surface of the concave. The dehusking and splitting also occur due to impact force. The mixture of husk, unhusked grains and splits falls from the bottom outlet of the machine. This mixture is simultaneously subjected to air blast, which removes the husk, and other lighter materials. The dehusked *dal* and splits are collected at the main outlet. It is claimed that the dehusking efficiency of 94%, 97% and 98% was achieved for soybean, chickpea and pea, respectively. The splitting efficiency of the machine is claimed at 98% with 10% broken.

CIAE dehusking and splitting machine

CIAE Bhopal has developed a low cost dehusking and splitting *dal* mill for rural use. The machine consists of an abrasive carborundum roller dehusker and has a capacity of 100 kg/hr. This machine can be owned, operated and manned by less skilled people of rural and semi-urban areas. The mill operates with a 1.5 KW, 3 phase electric motor. The cost of milling was estimated to be Rs. 14.0 per quintal. The average recovery in case of pigeonpea, mungbean and urdbean was claimed to be 75% and 74% each, respectively. As water treatment is recommended with the mill, the use of edible oil in the process of dehusking has been completely eliminated in this process.

CIAE Mini Dal Mill

PKV mini *dal* mill

The mill consists of four units *viz.*, splitting unit, sieve, aspirator and polisher. The premilling treatment is given by soaking difficult to mill pulses grains in sodium bicarbonate solution.

The splitting unit is comprised of two emery discs run 1.0 hp, single phase electric motor. One of the discs is fixed and another is revolving type. The clearance between them is adjusted by screw mechanism operated by hand wheel. The capacity of this unit is 40-45 kg per hour for pigeonpea and around 60 kg per hour for mungbean and urdbean. The sieve unit consists of two reciprocating type of easily removable. Different sizes of sieves are required for various grain sizes. It separates mixture in three different parts coming out from individual outlets, lower one is for broken, middle for *dal* and upper are retains the mixture of husked and dehusked grains. The aspiration unit consists of two blowers (aspirators) and a cyclone separator. One of the aspirator positioned near the outlet of splitting unit separates only husk and powder from the milled mixture and provides dust free operation. The second aspirator separates husk from *dal* moving from the polisher unit. Both the aspirators are connected to a cyclone separator, which collects powder from the mixture of husk and powder so as to avoid its spreading in the atmosphere. In polisher, polishing is done with the help of two screw conveyors wrapped with leather and enclosed in a casing. The friction of *dal* between leather and inner surface of casing enables to polish it and removes the husk, which still adheres to *dal*.

PKV Mini Dal *Mill*

It is necessary to give pre-treatment to pigeonpea grains before milling. Grains are soaked in 6% solution of sodium bi-carbonate for 40 minutes and dried. The grains of mungbean and urdbean do not require any premilling treatment. In case of pigeonpea, the maximum efficiency over 72% can be obtained. This machine is recommended to be use at cottage industries level.

CFTRI hand operated pulse dehusking machine

CFTRI, Mysore has developed a hand-operated abrasion type of machine for processing of pulses at household level. It can perform both dehusking and splitting operation while causing minimum breakage and powdering. The machine can dehusk 40-60 kg pre-conditioned pulse per hour. The suitably pre- treated pigeonpea, chickpea, soybean and peas are the pulses which can be dehusked by this machine. The husk and brokens are separated by winnowing and sieving. It is claimed that this machine can achieve 95-98% dehusking and the yield of head *dal* is obtained around 75-80%. Motorized version of this machine is also available. This machine is easy to operate, and can be maintained and repaired at rural level. This machine has been designed and developed with an intention of replacing the traditional *chakkis*.

CFTRI mini *dal* mill

This mill developed at CFTRI can dehusk 100-150 kg of pre-treated pulse per hour and is recommended to be used for tiny scale. The mill has a capacity to dehusk 100-150 kg of pre-conditioned pulse per hour. The mini *dal* mill consists to dehusking and splittting unit, aspirator and separator unit runs by 1 hp single-phase motor. Bold pulses such as pigeonpea, chickpea, peas and soybean can be dehusked in this machine.

CFTRI Mini Dal Mill

For mungbean and urdbean, splitting of unhusked grains can also be achieved in the mill. It is claimed that this mill gives a yield of 77-80% and dehusking efficiency of 97-99%. This is an integrated unit and comes with a grader, which runs on 1/2 hp single phase motor and can grade 200-250 kg of soaked (wet) pulse per hour. In this machine, grains are dehusked and split simultaneously. Dehusking is achieved by abrasion of grain between the rotating emery coated cone and wire mesh cage. Aspirator separates the husk and broken are segregated in the reciprocating sieve assembly. The dehusked and unhusked grains are collected at different points. The machine gives higher yield and good quality *dal* at comparatively lower processing costs. This technology ensures pollution free atmosphere besides low power consumption. This mini *dal* mill is simple in design, easy to operate and can be repaired and maintained at rural level.

Pantnagar manually operated *dal* mill

This mill is designed to be used by farmers at cottage scale with a view to enable them to market their produce after primary processing so as to augment their income. It comprises of hopper, screw conveyor, emery rollers and cylindrical separators. The mill has a capacity of 50 kg/hr. The mill can be operated with the help of paddles. The *dal* is treated with 10% sodium bi-carbonate solution followed by tempering and drying to 10% moisture content. It gives 75% dehusking for pigeonpea grains. The mill was found effective for urdbean, chickpea, soybean *etc*. The yield of head *dal* is 50 kg/hr and broken amount to 5-6%. Only one labour is required to operate this mill.

Pantnagar mini *dal* mill

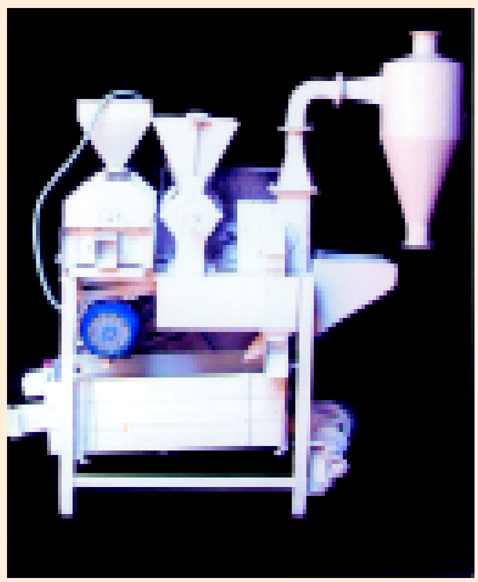
It consists of emery rollers, hopper, conveyors and separators. The machine is operated with the help of 1.0 hp motor and has a capacity of 100 kg/hr. This has been designed to process pigeonpea only. It requires five hours for the complete milling operation. The pre-treatment is done with the help of 10% $NaHCO_3$ solution. The milling yield is 50 kg/hr of dehusked *dal* and 80% dehusking efficiency can be obtained with this machine.

IIPR mini *dal* mill

The first prototype of IIPR Mini *Dal* Mill was developed in 1992, since then the various upgraded models of the mill have been developed and commercialized. About 175 units of this mill have been established in different parts of the country. The machine basically comprise of feeding unit, milling unit and cleaning unit. Feeding unit consists of a feed hopper and auger type feed mechanism, which maintains uniform flow of treated pulse grains to the milling unit. Milling unit is a vertical attrition unit, comprising of stationary rubber and rotating corrugated steel disks. Gap between the two disks can be increased or decreased depending on pulse crops and grain size of the cultivars. The milled product is exposed to air suction through a blower and, husk and powder is separated by means of cyclone separator. Due to use of rubber disk IIPR Mini *Dal* Mills yields 5-10% higher *dal* recovery for different pulse crops, when compared to emery roller type mills.

Since its evolution in 1992, IIPR Mini *Dal* Mill has undergone several upgrades. These upgraded models were developed based on feedback received from farmers and entrepreneurs using the machine. The latest model of the mill has the provision of grading raw material as well as finished product. Grading of raw material facilitates uniform gap between the disks during milling operation. Grading of finished product separates the different fractions of milled product. Apart from this, an emery roller of 3810 x 1524 mm is attached to the mill to carry out pitting operation. Pitting facilitates faster rate of pre-milling treatment and reduces residence time significantly. This roll also enables the mill to produce '*gota*' (dehusked whole) from lentil, called '*Malka Masoor*', which was difficult to produce in earlier models as most of the *dal* produced gets split in vertical attrition mills. Refinement in disk holding mechanism and quality of rubber disk has also been made. All pitting, milling, cleaning and grading operations can be done simultaneously in the new model. This machine can also be used for '*dalia*' making and making grits for animal feed. To produce '*dalia*' or grits rubber disk is replaced with steel disk to crush the material. Use of the machine can easily generate a monthly profit of Rs. 5,000/- per month along with providing employment for three. This mini *dal* mill has an immense potential for being exploited as cottage scale industry for the benefit of rural entrepreneurs, unemployed youth and progressive farmers.

IIPR Dal Chakki



IIPR Mini Dal Mill

Table 11.1 : Relative performance of three most popular mini *dal* mills

		IIPR *Dal* Mill	CIAE *Dal* Mill	CFTRI *Dal* Mill
Chickpea				
Raw grain	Dehusking efficiency	61.86 %	58.26 %	60.10 %
	Dal recovery	53.20 %	49.20 %	54.00 %
Soaked	Dehusking efficiency	90.23 %	88.00 %	89.00 %
	Dal recovery	77.60 %	68.70 %	76.50 %
Pigeonpea				
Raw grain	Dehusking efficiency	49.53 %	40.35 %	45.35 %
	Dal recovery	42.60 %	38.00 %	40.60 %
Soaked (11 h)	Dehusking efficiency	87.90 %	77.09 %	88.10 %
	Dal recovery	75.60 %	68.00 %	76.60 %
Oil & water treatment pigeonpea				
	Dehusking efficiency	98.90 %	79.86 %	98.20 %
	Dal recovery	77.20 %	51.40 %	75.80 %
$NaHCO_3$ treatment				
	Dehusking efficiency	95.20 %	85.48 %	94.75 %
	Dal recovery	75.38 %	50.70 %	72.20 %

12. Marketing of Pulses

Pulses are marketed as a raw whole as well as dehusked split. For marketing of pulses, quality of product becomes of prime importance. Cleaned and well-graded whole grains fetch higher prices. For dehusked splits, better packaging is required to reduce post-milling losses and to increase acceptability of consumers.

12.1 Quality standards

Quality specifications pulse grains

In order that commercial transactions can proceed properly and to the complete satisfaction of both sellers and buyers, realistic and practical legal standards should be adopted that clearly stipulate product quality, methods of ascertaining it, and marketing standards. Application of such norms is influenced by the degree of training for workers concerned with quality control and by the availability of specific equipment.

Based upon the requirement of trade and industry, quality standards have been developed for different pulses. These standards for some of the pulses are shown in the following table.

Pulse	Quality Parameters
Chickpea	For Rajasthan Desi (MP Desi quality meeting the same specifications will be accepted without any price difference) : i) The material should be free from Mathara and Khesari and live insect ii) Foreign matter : 1% maximum. iii) Green, immature, shrunken, shrivelled seeds : 3% broken, 2% split iv) Damaged and weeviled : 3% and 2% respectively v) Moisture : 10% vi) Other varieties : 1% maximum For MP Kantawalla variety : i) The material should be free from Mathara and Khesari and live insect ii) Foreign matter : 1% maximum. iii) Green, immature, shrunken, shrivelled seeds : 3 % iv) Broken and split : 3% v) Damaged and weeviled : 3% and 2% respectively vi) Moisture : 10% vii) Other varieties : 1% maximum

Pigeonpea	For Maharashtra Lal Tur : i) Foreign matter : 1% maximum including dust, sand and other admixture ii) *Kachri* – damaged otherwise (including immature, shriveled, heated, fungi and discoloured grains, broken, weeviled seeds : 3% maximum iii) Retention on 4 mm sieve : 2% iv) Red seeds : 95 % v) Moisture : 14% vi) Crop year : Current vii) The material will be tested on 4 mm sieve viii) The material should be free of live infestation For Myanmar Origin Lemon Tur : i) Foreign matter : 2% maximum including dust, sand and other admixture ii) Damaged otherwise (including immature, shriveled, heated fungi and discoloured grains) broken and weeviled seeds : 14% iii) Moisture : 14% iv) Crop Year : Current v) The material will be tested on 3 mm sieve. The material should be free of live infestation
Urdbean	i) Foreign Matter : 1.5% maximum including dust, sand and other admixture ii) Damaged otherwise (including immature, shriveled, heated fungi and discoloured grains) broken and weeviled seeds : 4% iii) Brown seeds : 3% iv) Sister beans : 3% v) Moisture : 14% vi) Crop year : Current vii) Small seeds (Passing through 2.75 mm slotted sieve): 6% maximum viii) Weeviled Seeds : 1.5% maximum. ix) The material should be free of live infestation
Yellow Peas	i) Colour : Fair colour ii) Other colours : 2% iii) Foreign matter : 0.5% maximum iv) Splits : 8% maximum v) Insect damaged : 0.8% vi) Damage : 3% vii) Sister beans : 3% viii) Shrivelled : 4% maximum ix) Moisture : 16% maximum

12.2 Packaging

Deterioration and losses of products, during transport and storage depend upon a series of physical, chemical, biological and human factors. Proper packaging is an important element in reducing losses, especially in the tropics. Climate considerably increases the risks of grain deterioration. The main functions of packaging are:

- to permit easy handling, whether manual or mechanical
- to reduce product losses by theft
- to protect the product from external attack (by humidity, insects, sunlight, *etc*.)

There are various types of packaging for agricultural commodities, appropriate to the product characteristics and to the marketing system. Woven bags made of plant or plastic fibers are the usual type used for grains. Reasonably priced bags, which fulfill the functions described above, can normally be made from such fibers. The choice of the type of bag should taken into account not only its inherent toughness and resistance to humidity, sunlight and pests but also the type of handling anticipated.

Plant-fiber bags

A number of plant fibers like jute, cotton, and sisal are used for making bags for packaging of pulse grains. The choice of packaging material depends upon packaging requirement.

Jute bags : The jute bag is the most widely used packaging material in the world. It combines good resistance capacities with a relatively moderate cost. It can be re-used several times since it has good inherent toughness, which reduces the risks of tearing. In addition, it protects the grain effectively from sunlight. However, with its relatively heavy fibre with a coarse texture makes it inappropriate for small-size grains. Furthermore, jute easily absorbs humidity and offers little resistance to the attacks of insects and rodents. In order to partially offset the disadvantages of humidity absorption, these bags can be lined with plastic or, if necessary, covered with waterproof tarpaulins. Handling jute bags is easy because the material is not slippery. As a result, fairly high stacks can be erected.

Cotton bags : The cotton bag is used for packaging value-added products obtained after processing, such as flours or sugar. Actually its features are practically the same as those of jute, except that the cotton bag is lighter, harder to sew, and more costly.

Sisal bags : The sisal bag is rougher than the other plant-fiber bags and is seldom used except in sisal producing countries like Mexico, Brazil and some African countries. Its features are comparable to those of jute bags.

Paper bags : They are more vulnerable and require more delicate handling. They offer very little protection against humidity and insects, and must be stored under good conditions. They are used especially for packaging seeds.

As for the other plant fibers, hemp and linen, they are virtually no longer used for bags because of their high costs.

Plastic-fiber bags

PP woven bags : These bags are made of plastic (polythene) woven fabrics, or of mixed fabrics (plant fiber and plastic fiber). Polythene bags are widely used for packaging grains and they seriously rival the traditional jute bag. These bags have the advantage of being resistant to moisture transfer, rot-proof, and impermeable to insect pests. However, they should be suitably treated in order to resist sunlight, since polythene deteriorates when exposed to light. With good treatment, a polythene bag can be re-used for 6-12 times. They cost less than jute bags and are harder to handle. Their surface is very slippery, and so they cannot be stacked very high.

Polyethylene bags : The most commonly used material for such bags is polyethylene and polyester. These bags are not moisture-proof but are moisture resistant. They deteriorate easily if exposed to sunlight, therefore, should be protected from direct sunlight. They are difficult to stack as bags may slide and fall down).

Type and size of the bags

The choice of bags invariably depends on the material to be packed. The size of bags should take into consideration :

- The amount of material required by the consumers
- The average men's capability to carry it during loading or unloading
- Ease in handling by the consumers during transport

In general, jute, cloth and pp woven bags are used for packaging of pulse grains in bulk in sizes of 50 kg or 100 kg. Polyethylene bags are preferred for packing of pulse grains and value added products for retail trade. Size of these packages may vary from 500 g to 5 kg. In any case, the bags should be :

- Easy to handle, transport and store
- Strong enough to avoid losses and to protect against mechanical damage.

12.3 Adulteration in pulses

What is adulteration?

Pulses in the diet acts as a fuel for body and mind to keep it fit and working. Many times pulses purchased from the market are either adulterated with *khesari* (Lathyrus) *dal* or some low-priced *dals* or are coloured with some undesirable colours to improve its appearance, which are harmful for the health. With high degree of sophistication in method of adulteration, it becomes imperative that pulses to be consumed should be pure and wholesome. A common consumer may not have sufficient knowledge about the impurity and quality of the pulses. Awareness about necessary means to verify or test its quality is also lacking. Mere visual inspection does not serve purpose. Consumer awareness is the remedy for eliminating this evil of adulteration and sale of sub-standard product.

Test for adulteration

Some simple and quick tests are available which can be easily performed to ascertain the purity of *dal* or *besan* if it is adulterated with *khesari (Lathyrus) dal* or the presence of some harmful chemicals in the form of colouring agent. The available tests are given as under :

Simple screening tests for detecting adulteration in pulses

Sl. No.	Food article	Adulteration	*Test*
1.	Pulses/*Besan*	*Khesari dal* (*Lathyrus sativus*)	Add 50 ml of HCl to a small quantity *dal* and keep on simmering water for about 15 minutes, The pink colour, if developed, indicates the presence of *khesari dal.*
2.	Pulses	Metanil yellow (dye)	Add conc. HCl to a small quantity of *dal* in a little amount of water. Immediate development of pink colour indicates the presence of metanil yellow and similar colour dyes.
3.	Pulses	Lead chromate	Shake 5 g of *dal* with 5 ml of water and add a few drops of HCl. Development of pink colour indicate the presence of lead chromate.

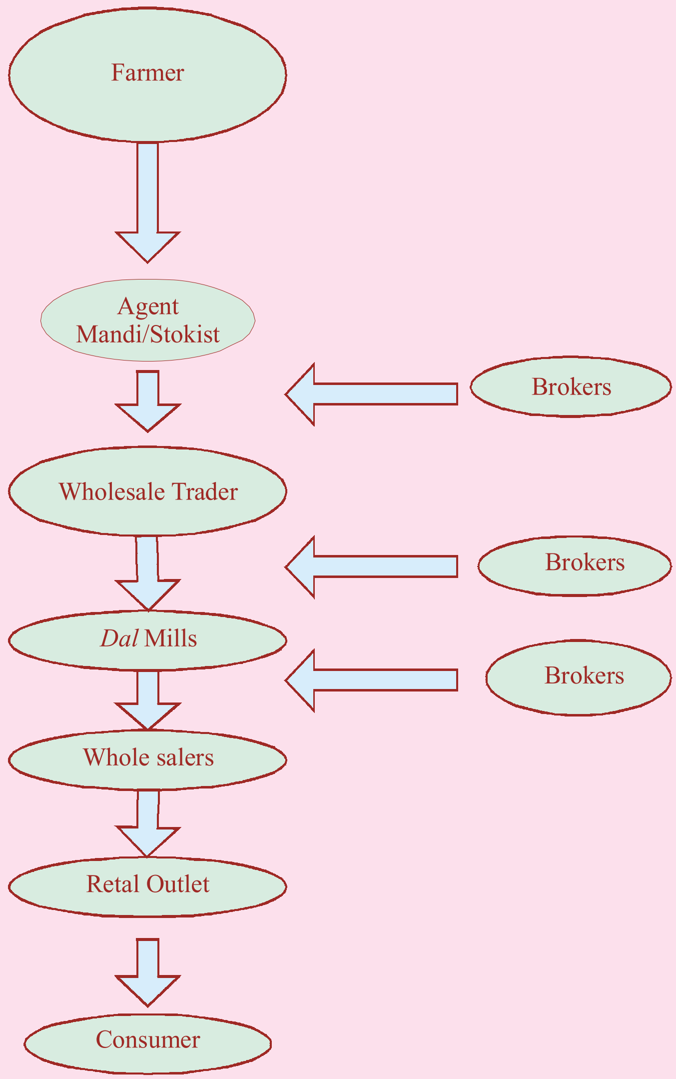
13. Trading of Pulses

Important production and trading centers in India

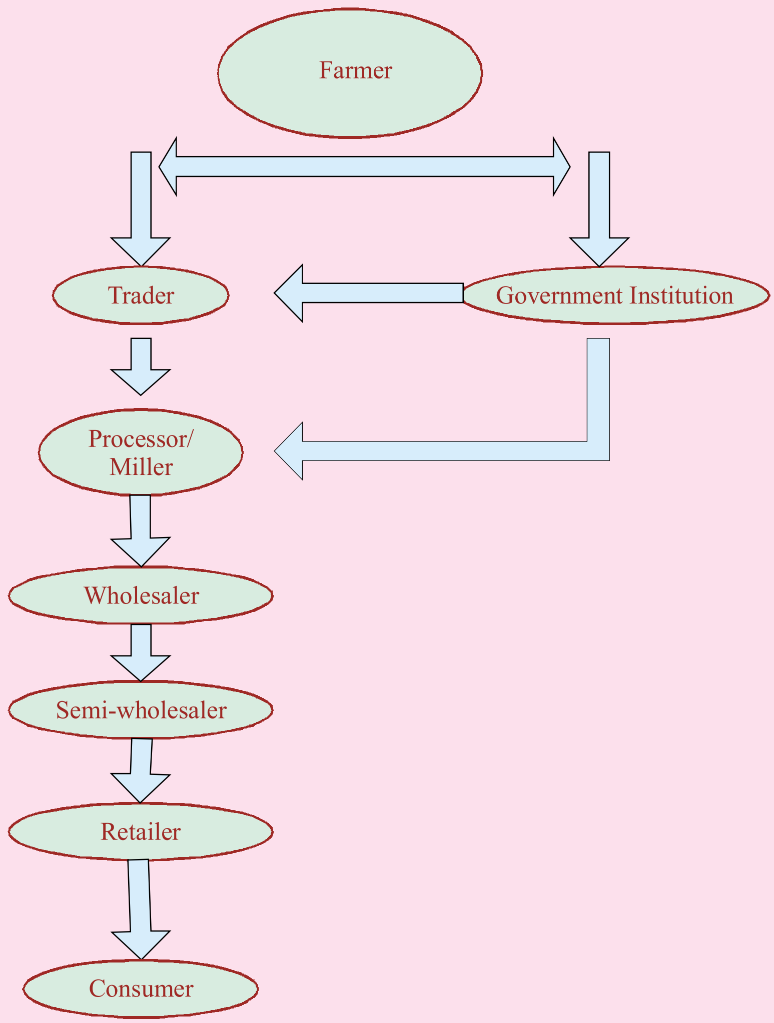
Crop	Major growing states	Key trading centers
Chickpea	Maharashtra	Akola, Barsi, Jalgaon, Latur, Mumbai, Udgir
	Rajasthan	Bikaner, Hanumangarh, Jaipur, Jodhpur, Kota, Sriganganagar
	M.P.	Bhopal, Indore, Vidisha
	Delhi	Delhi
	Haryana	Adampur, Sirsa
	Karnataka	Gulbarga
	Andhra Pradesh	Vijaywada
Pigeonpea	Andhra Pradesh	Adilabad, Narayanpet, Alampur, Karimnagar, Warangal, Vijaywada, Tenali, Suryapet, Miryalaguda, Vizianagaram
	Karnataka	Sedam, Gulbarga, Bidar, Raichur, Yadgir, Shorapur, Banglore, Haveri, Bijapur, Chitradurga, Mysore, Kollegal, Devengere
	M.P.	Jabalpur, Shahpura, Katni, Tendukheda, Chhindwara, Betul, Rewa, Bhopal, Gairatganj, Udaipura, Kannod, Dabra, Bhind, Alampur, Lahar, Indore, Khandwa, Burhanpur, Harsud, Sagar, Damoh, Ajaygarh, Loundi, Dewas
	Maharashtra	Jamkhed, Karjat, Kopargaon, Newasa, Parner, Rahuri, Sangamner, Shevgaon, Shrigoonda, Shrirampur, Dhule, Akola, Dondaicha, Baramati, Sangli, Solapur, Aurangabad, Jalna, Murud, Nagpur
	Uttar Pradesh	Kanpur, Varanasi, Gorakhpur, Agra, Allahabad, Hathras, Lucknow, Bahraich, Banthra, Ballia, Robertsganj, Bareilly, Meerut, Sitapur
	Gujarat	Surat, Dhansura, Rajkot, Talod

Urdbean	Jammu & Kashmir	Jammu
	Tamil Nadu	Chennai, Tuticorin
	Delhi	Delhi
	Jharkhand	Koderma
	Karnataka	Banglore, Bhadravathi, Hassan
	Uttar Pradesh	Lakhimpur, Lalitpur, Kanpur, Aligarh
	M.P.	Indore, Bhopal, Jhansi, Vidisha
	Gujarat	Madosa, Rajkot, Junagarh
	Maharashtra	Latur, Jalgaon, Akola, Dhulia
	Andhra Pradesh	Vijaywada
Yellow peas	M.P.	Indore, Bhopal, Vidisha
	Maharashtra	Mumbai, Jalgaon, Akola
Mungbean	Rajasthan	Kherli, Ganganagar
	Karnataka	Yadgir, Bidar, Shimoga, Bangalore
	Gujarat	Bhuj, Disha, Paton, Bhabar, Deodar
	Maharashtra	Parbani, Jalna, Akola, Latur, Ahmednagar

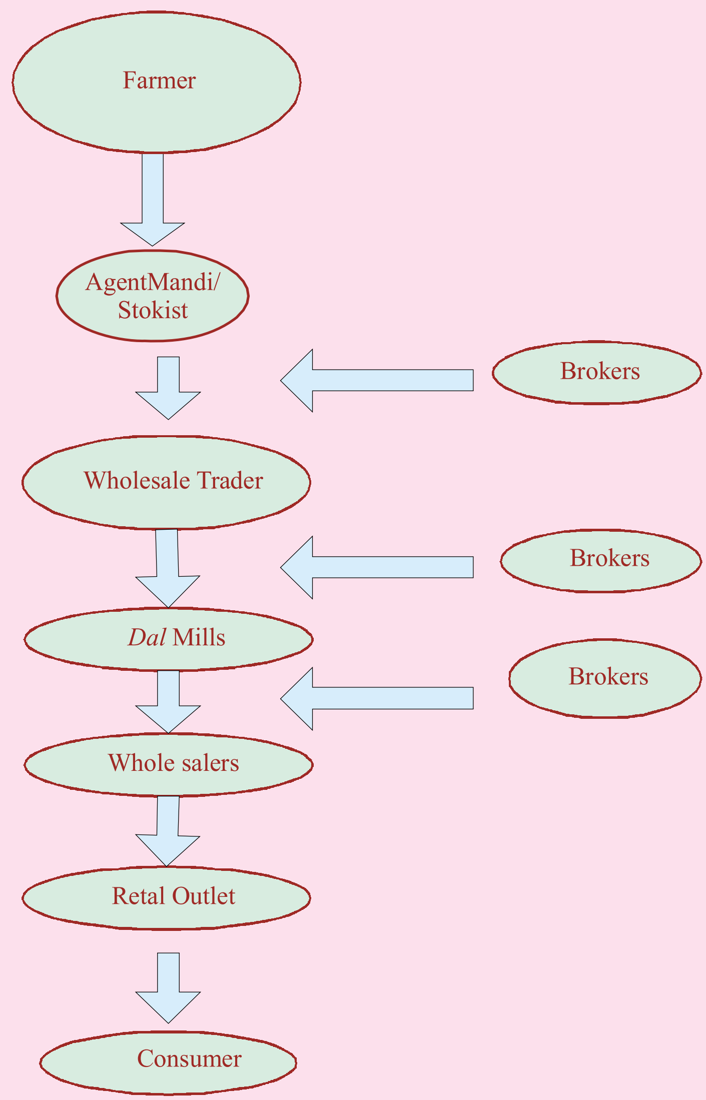
Value chain of pulses



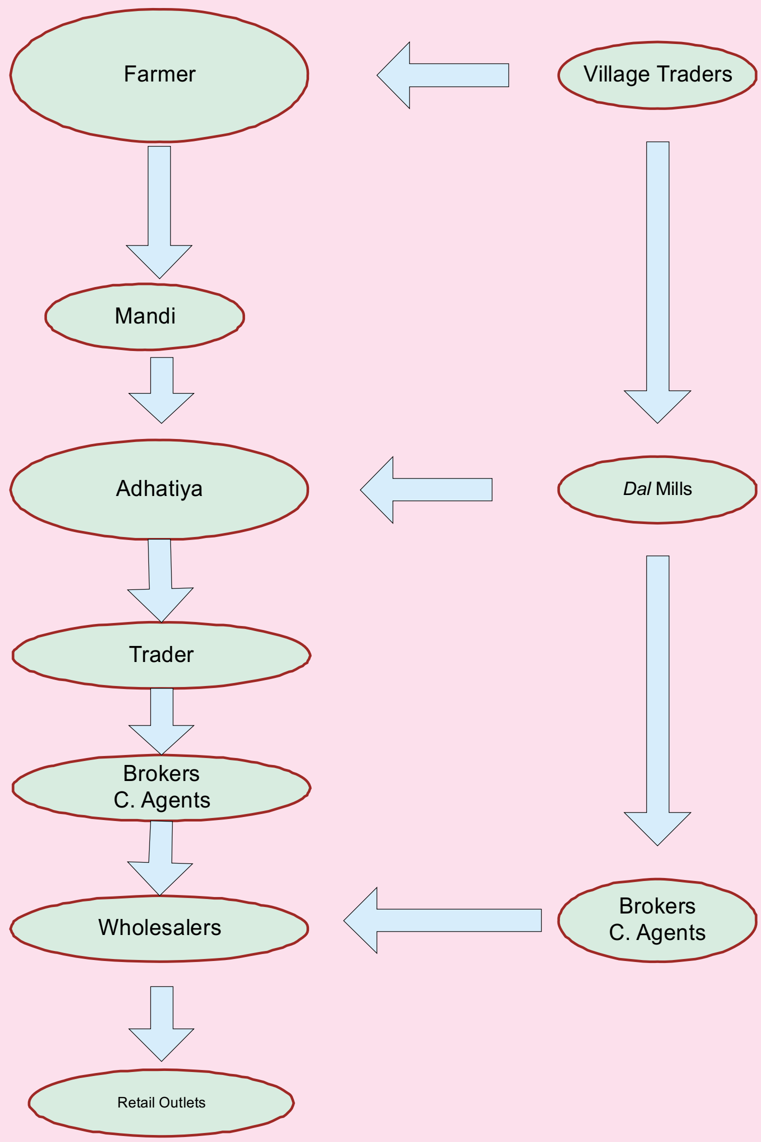
Value Chain of Chickpea



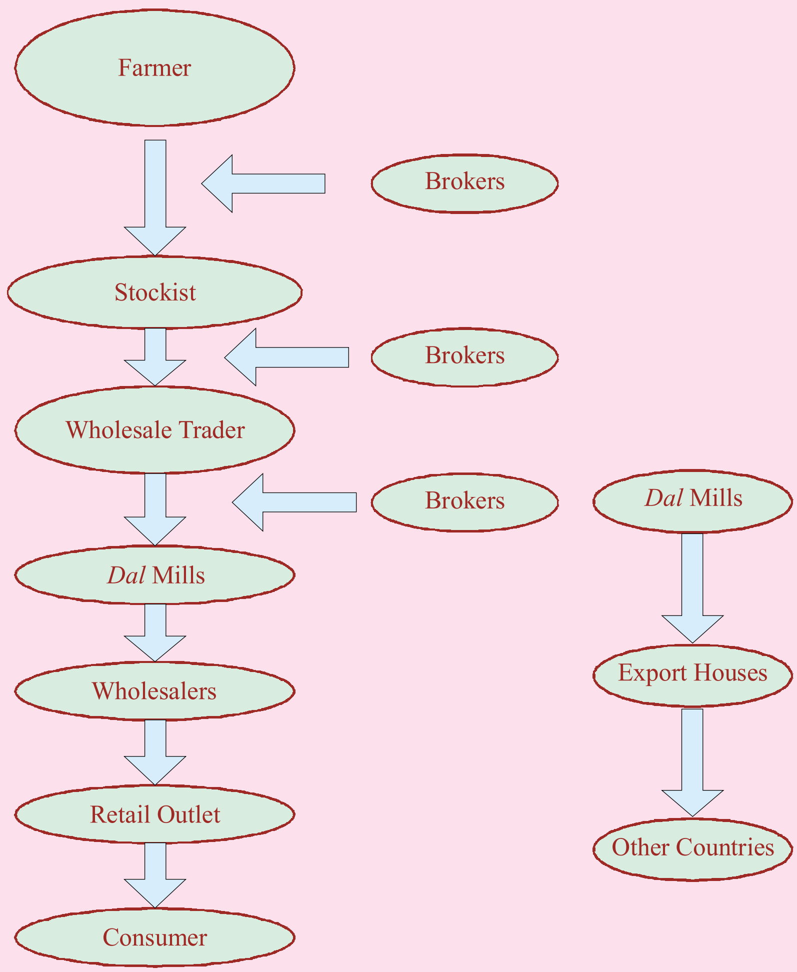
Value Chain of Pigeonpea



Value Chain of Urdbean



Value Chain of Mungbean



Value Chain of Lentil

Epilogue

Pulses form an integral part of Indian diets. Being are rich source of protein, their major importance lies as supplement to cereal based diets. Pulses not only add to the quantity of protein in the diet but also improve its qualities by balancing the essential amino acid pattern in the mixed diets. India is a major producer of pulses in the world. A number of varieties of pulses are grown and consumed in a variety of food products after suitable processing. Apart from common pulses like chickpea, pigeonpea, urdbean and mungbean, a good number of other pulses which are generally referred to as minor pulses like cowpea, horsegram, lentil, mothbean *etc*., are also produced and consumed in different regions of the country. The present annual production of pulses is about 15 million tonnes and this has remained stagnant since last 3 decades. As a result, the availability of pulses has fallen to about 35 g per capita per day. This is about half of what is actually required for proper nutrition as per the recommendations of Indian Council of Medical Research.

Interaction of grain and machine parameters in relation to yield and quality of milled products is another area, which requires attention. Milling systems of future may involve heat treatment as promising approach. Heat treatment is invariably involved in pulses drying. Therefore, influence of temperature and time combinations at various grain moisture on pulse nutrients, pre-treatments and milling quality need to be systematically investigated. Various pre-treatments and other processing efforts may involve losses of nutrients, which need to be estimated.

Under every milling process, certain mixture of unhusked and fully husked grains are expected. The fully husked grains must be separated to avoid their scouring in recycling. As of now, efficient separation techniques are not available. There is need of a proper conditioning system to enable dehusking and splitting without causing processing losses. Various conditioning systems under different names were developed and adopted by the pulses processing industries ever since 1930s.

Like paddy milling, quality of a pulse cultivar developed is an important criterion, which contributes towards its acceptability for cultivation. Evaluation of milling quality requires standardization of the technique and apparatus.

Improved system of conditioning, incorporating there in all the good features of the existing conditioning systems came into being as a result of the research and development work done by various Research and Development institutions and industries. The advance systems as available now, eliminates the processing losses almost completely and there is no powdering and kibbling adding yield by 2-8% (depending on the variety of pulse processed and the processing losses occurring therein). The quality of the product namely, the dehusked splits, is much better.

No matter how efficient is the process, the broken and powder formation is bound to occur, appropriate technology for their utilization like *dal* analogue, as human food should also be considered as an important theme from research view point.

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