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HANDLING, MANAGEMENT, AND MARKETING OF CEREAL GRAINS

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USA

REFERENCE MANUAL

HANDLING, MANAGEMENT, AND MARKETING OF CEREAL GRAINS

REVISED EDITION

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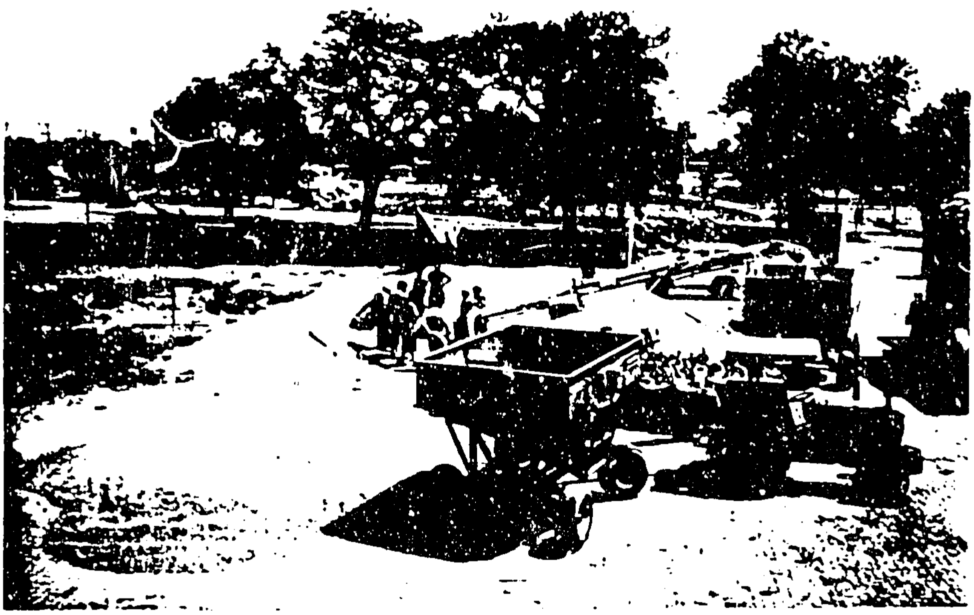

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PREFACE

Storage of grains is one of the oldest activities of man. Those who care for our food supply are professionals in the truest sense of the word. New discoveries constantly add to our knowledge of grain protection, and the professional strives to improve his skills in storing and protecting grains. This manual is dedicated to those involved in grain storage in Pakistan. It brings together the knowledge of those working with stored grains in this country and useful information from other countries.

As Pakistan moves toward a new era in grain storage and handling by adopting the bulk grain system, grain storage managers will need new skills and knowledge to deal with the change. His work will require more knowledge about a variety of subjects. The work pattern will shift from a high physical activity to a mental one. The grain will move faster, and the manager will have less time available for decision making. He will have more responsibility in the management of grain stocks.

The storage of grain is complex. It involves nearly every field of knowledge such as biology, biochemistry, mathematics, physics, and economics, to name a few. The manual treat some subjects in detail to provide knowledge for the day-to-day activities related to grain protection. Other topics are background information to create a better appreciation of the hows and whys of grain storage. Despite its complexity, the safe storage of grain is a relatively simple and straight-forward process. This is true if one knows and follows a few basic rules concerning grain preservation.

Many people contributed to the preparation of this manual. Their collective effort has produced a manual which is easy to read and understand. The many illustrations should assist the user to capture the concepts being presented. The review questions should aid in recognizing the salient points discussed in each chapter. The annexes provide in-depth discussion of some topics concerning grain preservation and pest control.

This manual is specifically dedicated to the operational personnel of the Provincial Food Departments and the Pakistan Agricultural Storage and Services Corporation (PASSCO). However, it should also benefit grain storage workers in the private sector and students of local agricultural colleges and universities.

The preparers of this manual received valuable information from "Master Trainers" on problems and opportunities for improving grain storage in Pakistan. They gratefully acknowledge the valuable support and encouragement provided by the two organizations mentioned above. They give particular thanks and appreciation to the Vertebrate Pest Control Project for providing audio-visual aids and a companion manual dealing with the subject.

R. C. Maxon

CHAPTER 1

INTRODUCTION

Human beings used cereal grains as a staple food for the last 10,000 years. Evidence shows that ancient civilizations produced cereal grains and stored it to have food supply during periods of scarcity. This is about the time when man began to raise and domesticate plants and animals for food.

A. Importance of Cereal Grains

Wheat, rice, and maize are the three most important cereal grains used as staple food in the world. In Pakistan, wheat is the principal source of the daily calorie and protein intake of the population with the balance coming from animal sources. In the Far East and South East Asian countries, rice is the principal calorie source while meat and fish is the principal source of their protein intake. Meanwhile, in many Latin American countries, maize is the principal source of their calorie intake and meat is the main source of their protein daily intake.

B. Food Preservation

In the prehistoric period of agriculture, our ancestors observed that dry grains stored longer than wet grains. They also learned that insects and animals destroyed their crop both in the field and in storage. Based on their experiences, they devised primitive control measures to protect their food supply like using jars (Figure 1.1) to store their food grain. However, it was only in the last century that we learned more about the environment and how to control it. Major advancements in grain production and grain conservation occurred only in the last 50 years. This came about after the so-called green revolution era.

In spite of our increased knowledge both in grain production and conservation, we continue to lose grains from production to consumption. This condition is particularly more severe in developing countries than in developed economies. For this reason many countries launched programs specifically to reduce grain losses in developing countries. Many countries now realize that tons of grain saved are tons of grain not to import. In some countries, the level of losses represents the difference between having adequate and inadequate food supply.

From postharvest loss assessment studies many countries also realized that the factors causing their grain losses are similar with those in neighboring countries. This realization led to the formation of regional cooperative postharvest grain storage programs in Asia, Southeast Asia, Latin America, and Africa. Two examples are the ASEAN Grains Postharvest Program and the Association of Food Marketing Agencies in Asia and Pacific.

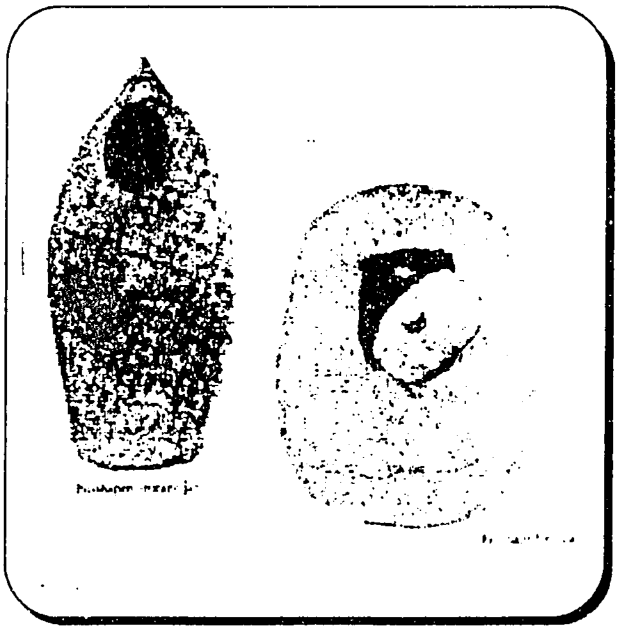


Figure 1.1.Pre-history jars used to store grains.

C. The Food Grain Cycle

Regardless of the technology that exists in a country, providing food requires the same activities from land preparation to marketing of grains. The diagram in Figure 1.2 shows the entire series of activities from production to marketing of food and feed grains. Each of the various activities determine the quality and quantity of grain available to the end users. Social scientists and engineers continue to study critical areas in grain production and post-production activities. They identify the factors that determine the success or failure of food systems. Their findings help planners of donor agencies prepare technical food aid programs for Third World countries to become self sufficient in cereal grains. They include programs on how to conserve what they produce by means of improved handling and food storage technologies. In the early 1970s, development programs focused heavily on reducing the gap between production and consumption. This focus continued on into the 1980s.

D. Important Factors in Cereal Production

1. Agricultural System - Studies show that methods of planting, climatic conditions, and land ownership contribute to grain losses. As an example, cereal grains grown in rainfed

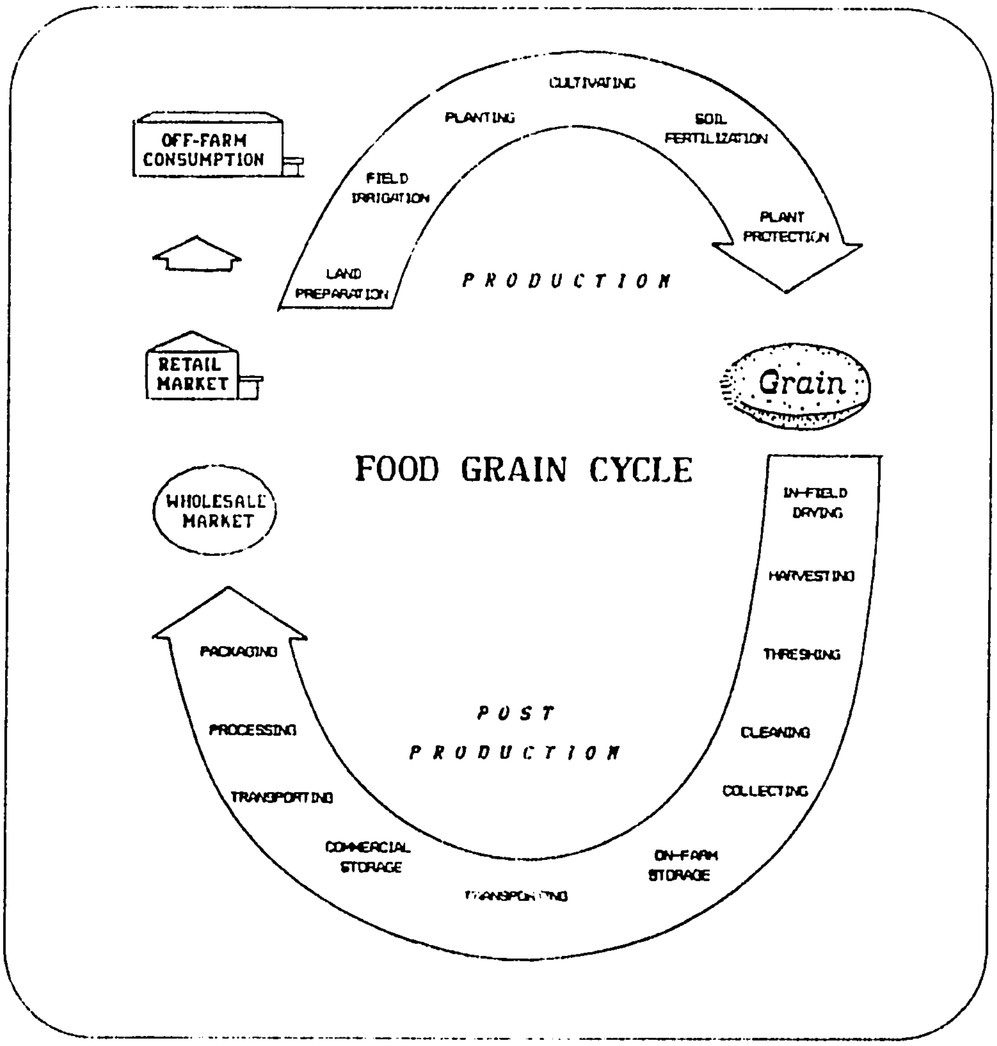


Figure 1.2 Diagram of the food grain cycle.

areas have the tendency to shatter because of low moisture contents at harvest. Methods of harvesting, handling, and transporting also contribute to grain postharvest losses. On the other hand, under tropical climatic conditions, the grains may start to sprout while waiting threshing in the fields.

2. Research and Development - To minimize these types of losses, scientists continue to develop varieties of rice and wheat that resist shattering and have a longer dormancy period. They also developed varieties that can resist pest and diseases.

Meanwhile, some innovative agricultural engineers tried to develop a grain stripping machine to harvest grains without cutting the plant. However, the grain stripper was impractical to use and left many unharvested grains in the fields. They then shifted their attention and succeeded in developing machines like the reaper and the portable thresher. Both machines are now very popular in many developing countries today like in Pakistan and China.

The combine is also a harvesting machine that is gaining popularity in many developing countries like Pakistan and Thailand. Thailand is now on the verge of developing its own combine suitable for use in wetland conditions. It is much lighter than their counterparts in Europe or the U.S. and simple in design for ease of local fabrication.

3. Technology Transfer - The introduction of the high yielding varieties of grains during the Green Revolution in the 1960's increased grain production worldwide. The rapid increase in grain production strained the traditional methods of handling, storage, and marketing of grains. However, in trying to strengthen a link in the entire food chain other links begun to show their weakness. The higher productivity gave rise to the so-called **second-generation problems** in the grain industry. This included the need for better methods of grain handling, drying, storage, and processing. However, modern grain processing and protection technology require higher technical skills to use them. Hence, research, training and extension are necessary components in the successful adoption of improved grain postharvest technology. There is a need to search for answers and continue in training personnel involved in grain handling and storage. As an example, insects constantly change their response to chemical control measures thus requiring new methods of control.

Advances in electronics and chemistry provide new technologies applicable in the grain industry. Similarly, new grain varieties may require different handling, processing, and storage techniques in the future. Thus requiring new cadre of storage managers and marketing specialists.

REVIEW QUESTIONS

1. *What factors contribute to grain postharvest losses?*

2. *What gave rise to the so-called Second-generation problems?*

3. *Enumerate three major postharvest problems in your locality.*

4. *Why aretraining and extension programs so important in the grain industry?*

CHAPTER 2

PROPERTIES OF CEREAL GRAINS

The grain is a valuable source of energy, protein, and vitamins for humans and animals alike. It is because of its food value that grains are vulnerable to predators both before and after harvest.

A. The Grain

The grain is the mature fruit of the cereal plant. During its formation, complex biochemical processes occur where sugars are synthesized into starch, amino acids into proteins, and glycerin into fats.

Like all agricultural products, cereal grains have physical, chemical, and biological properties that influence their stability in storage. A knowledge of these properties is vital in successfully storing and conserving grains and grain products.

B. Structure of Cereal Grains

All cereal grains belong to the grass family *Gramineae* and have a similar basic structure. Each kernel is a "mature fruit" of the grass plant. The fruit or Caryopsis has two main parts. They are the seed and pericarp. The seed is the source of food while the pericarp serves as the protective covering of the seed.

1. Parts of a Seed

a. *Seed coat* - It is a very thin material that encloses the seed. The seed coat holds the pericarp very tightly that they end up composing the bran after milling.

b. *Endosperm* - It is actually the food storage for the new plant. It is the largest part of most seeds (about 80%). It contains carbohydrates and proteins. The endosperm is a very valuable source of food for humans and animals.

c. *Embryo or germ* - It is the source of the new plant. It represents about 2.5% of the grain and contains fats, proteins, and vitamins. Molds and rats like to attack the germ. Vegetable oil companies extract the fat from the germ for the production of cooking oil and margarine. Figures 2.1, 2.2, and 2.3 show the structure of wheat, corn, and rice, respectively.

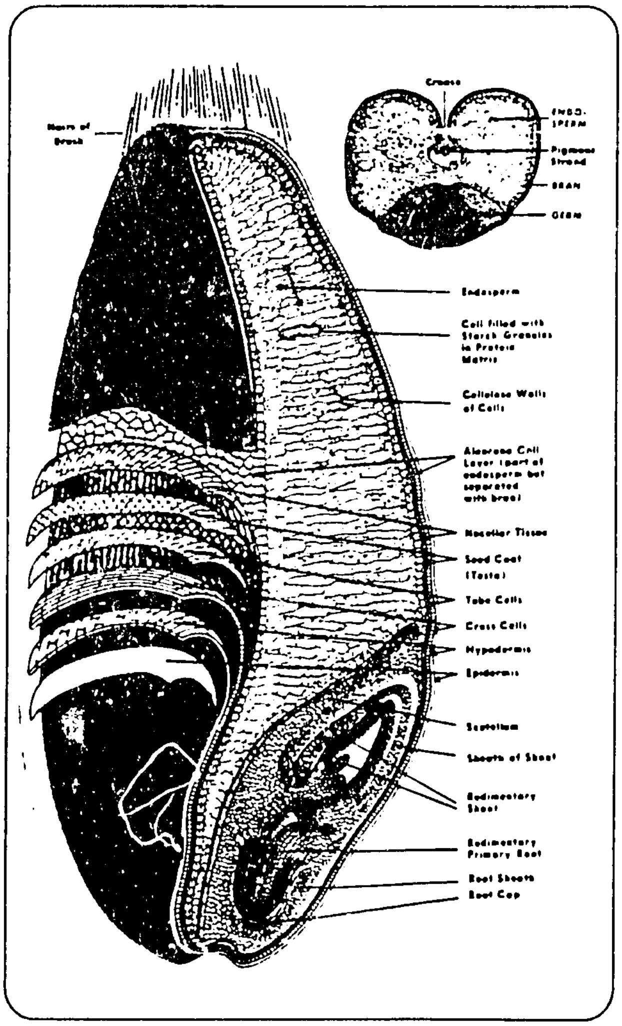


Figure 2.1 . Structure of a wheat kernel.

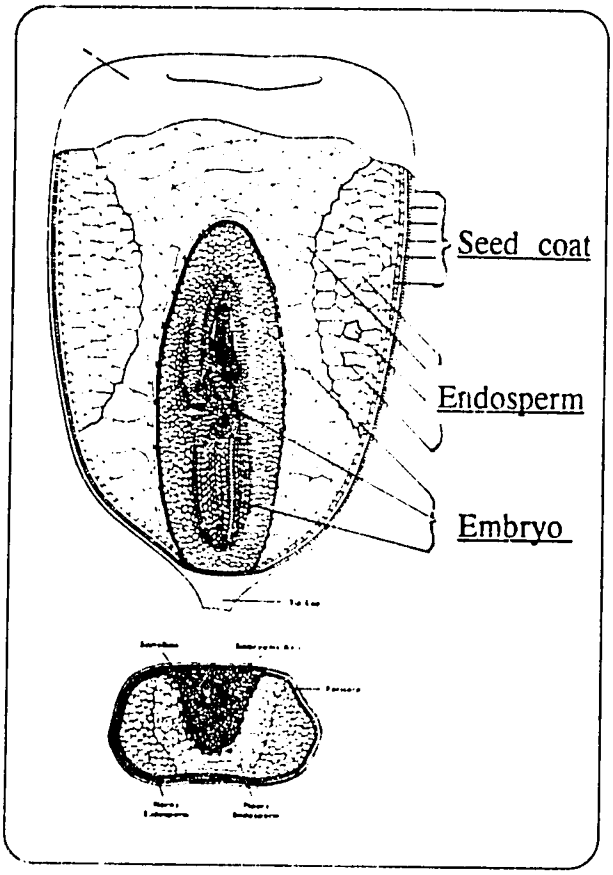


Figure 2.2. Structure of a corn kernel.

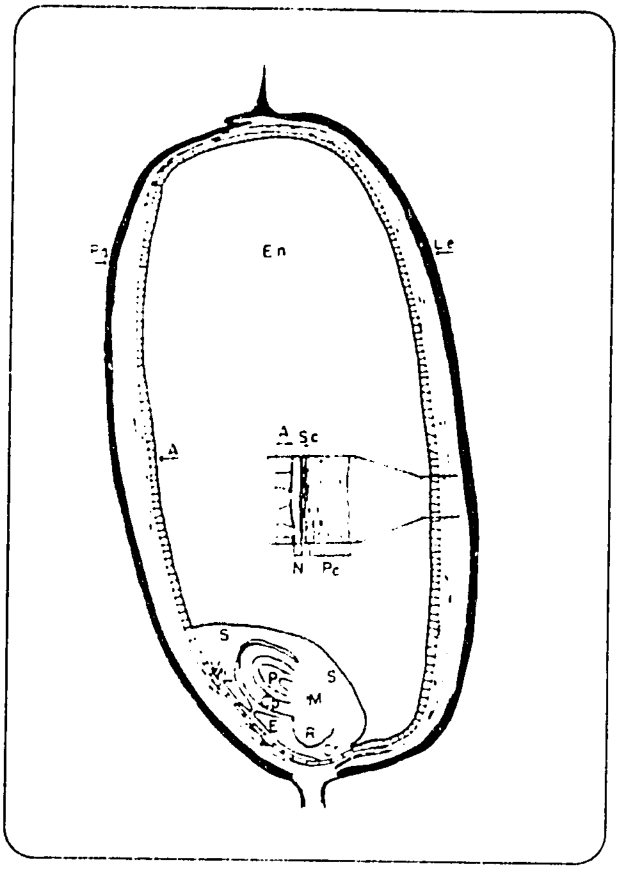


Figure 2.3. Structure of a rice kernel.

C. Physical Properties

Grains have properties that are important in designing and managing grain handling, storage, and processing systems. These properties vary with the kind of grain, their past treatment, and length of storage. Many engineers and scientists spent years and money in determining these grain properties. Table 2.1 gives the values of some of these physical properties. These values are very important in designing grain storage and drying systems.

Some important properties of grains are the following:

1. <u>Bulk Density (Specific Weight)</u>

Bulk density is the weight of the grain per unit volume. This is equivalent to pounds per cubic feet in the English system or Kg. per cubic meter in the metric system (Figure 2.4). Other units of bulk density are kilogram per hectoliter or pounds per bushel. Bulk density affects the capacity of grain bins, silos, and conveying equipment. Table 2.2 is a conversion table for units of one system to the other.

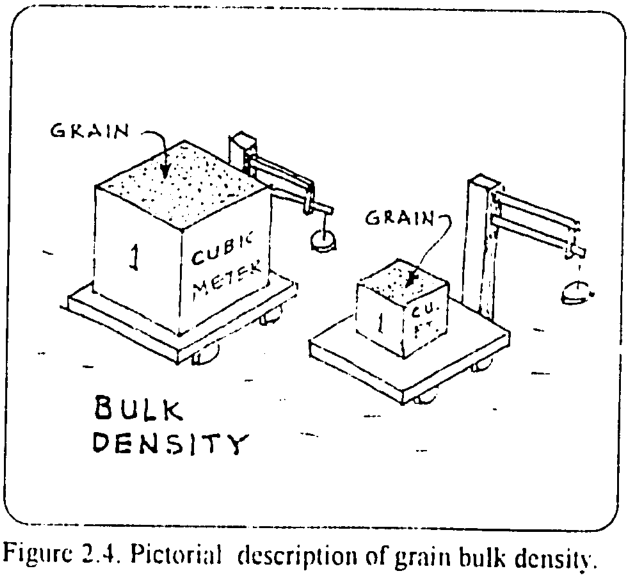


Figure 2.4. Pictorial description of grain bulk density.

2. Percentage of Voids - Percent void is a ratio between the air spaces in the grain mass to the total volume of the grain (Figure 2.5). This ratio is always less than one. Multiplying this value by 100 will convert it to percentage. It affects the bulk density and the resistance of bulk grains to airflow during aeration and drying. This property changes with the presence of foreign materials in the grain. The percentage of void spaces also affects gas movement during fumigation. The penetration of fumigant gas in the grain mass is very important in the effective control of insect infestation.

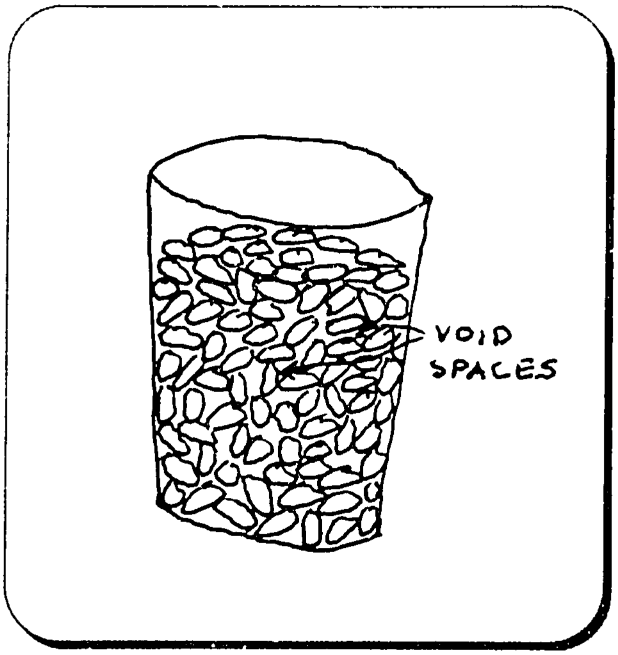


Figure 2.5. Void spaces in a glass of grain.

3. Angle of Repose - The surface of a grain pile forms a natural angle with a horizontal surface as they fall freely pile. The slope formed is the grain's angle of repose (Figure 2.6). The unit of the angle of repose is in degree angle. The grain moisture, kernel shape, and foreign materials present all affect the angle of repose. The angle of repose determines the slope of the bottom of hoppers or silos and spoutings. It also affects the lateral pressures on the storage structure. The angle of repose is inversely proportional to the lateral pressure it exerts on the silo wall.

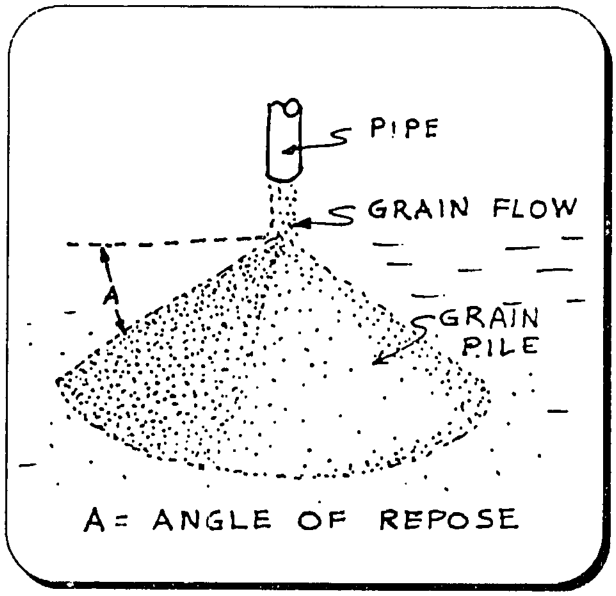


Figure 2.6. Schematic drawing of bulk grain angle of repose.

4. Coefficient of Friction - It is a ratio between the force that moves a body at rest to the force pressing the body against the surface. For example, grains slide on an inclined surface because of the force of gravity. However, frictional forces offered by the surface resist the sliding motion.

The coefficient of friction is therefore a ratio between these two forces, (Figure 2.7). The coefficient of friction of an object sliding against another is always less than one. In practical terms, corn grain slides more readily on a steel surface than it would on plywood. Similarly, corn grain slides more easily than paddy rice on a similar surface.

The surface characteristics of materials determine the their coefficients of friction. Smooth surfaces have lower coefficients of friction than rough surfaces. Hence, the coefficient of friction of the grain and construction materials determine the design of conveyors and silos. Meanwhile, the use of lubricants in machine parts reduces the coefficient of friction between the surfaces.The reduction in the coefficient of friction increases the efficiency and life of a machine.

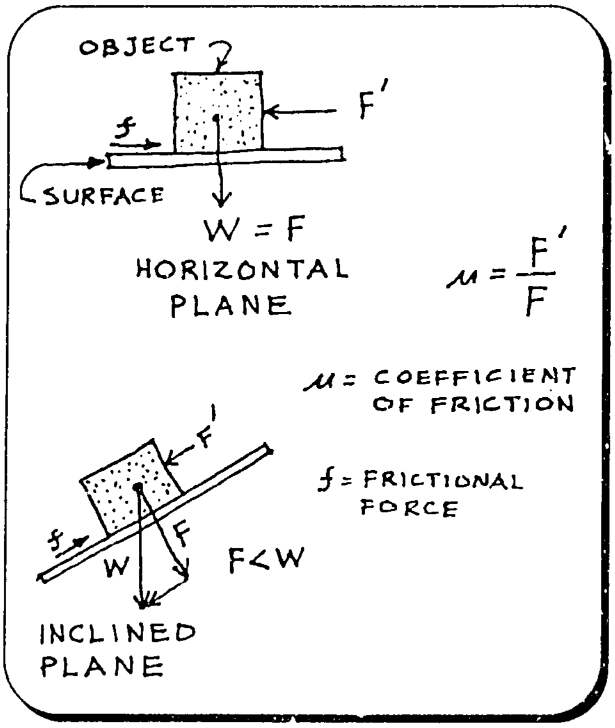


Figure 2.7. Diagram illustrating the forces acting on a solid body resting on a surface.

5. Specific Heat - Specific heat is the energy required to raise the temperature of a unit weight of substance one degree temperature. Specific heat has units in Btu per pound per degree Fahrenheit or calories per gram per degree Centigrade. For example, the specific heat of pure water is 1.0 cal/gram / ^{o}C while heat grain has 0.46 cal/gram/ ^{o}C . The specific heat of a grain approaches that of water as its moisture content increases. Knowing the specific heat of a grain is indispensable in solving grain drying and aeration problems.

6. Thermal Conductivity - It is the ability of a substance to transmit or conduct heat. Materials with low thermal conductivities are poor conductors of heat. Grains have lower thermal conductivities than metals and solid materials like concrete. Therefore, grains dissipate heat very slowly which may lead to heating and related problems in stored grains.

This is why bulk grains require an aeration system to remove excess heat in the grain mass and to equalize its temperature. Uniform grain temperature minimizes moisture translocation. Moisture translocation causes grain spoilage in stored grains. The translocation of moisture within the mass of grain is a common problem in bulk storage systems. Stored grains either in bulk or bag forms always have temperature gradients because they are poor conductors of heat.

For comparison, the thermal conductivity of steel is 60 times that of concrete while concrete is six times that of grains. An aluminum sheet metal has a thermal conductivity five times that of mild steel. This property determines what material to use in the construction of storage structures. Table 2.3 gives the thermal conductivities of grains and materials used in making silos and conveying equipment. There are other important physical properties of grains but are beyond the scope of this Reference Manual.

D. Biochemical Properties of Grains

There a number of biochemical properties of grains. A detailed discussion of all biochemical properties of grains is beyond the scope of this manual. However, this chapter will discuss those that are of immediate concern to grain traders and storage managers. The recognition of the relationship between some of these properties is very important in successfully storing grains

1. Moisture Content - It is one of the very important biochemical properties of grains. The moisture content of most cereal grains at harvest is well above the levels safe for storage. The reduction of moisture to about 12-13% is of concern to producers, storage managers, and processors. Drying is a process that removes the excess moisture in grains.

The three forms of moisture contained by cereal grains are free, unbound and bound.

a. *Free moisture* - It is a thin layer of moisture on the surface of grains. It is therefore similar in behavior to liquid surface water. Moisture that condenses on grains and other surfaces is free water. This water evaporates first during grain drying.

b. *Unbound moisture* - Unbound moisture is the moisture the grain holds in vapor form. Natural or artificial drying removes this moisture. The quantity of this moisture in the grain affects the stability of the grain in storage. Microorganisms may develop rapidly in grains when this form of moisture is high (see Chapter 6 for calculation of grain moisture and Annex A for moisture measurement procedures).

c. *Bound moisture* - It is the moisture of cereal grains held strongly by the molecular forces in the grain structure. One can not remove bound moisture by ordinary drying. This moisture is of little concern to the grain storage operator.

2. Moisture Movement - All cereal grains are hygroscopic materials. They have the ability to gain or lose moisture with the surrounding air. The losing or gaining of moisture is a sorption process. When moisture moves from the grain to it surroundings, the movement is a desorption process. When moisture moves from the surrounding air to the grain, the movement is an adsorption process. Drying is a desorption process because the moisture leaves the grain. The re-wetting of grains with water vapor is an adsorption process. The re-wetting of grains with liquid water is an absorption process. The illustrations in Figure 2.8 show the three processes of moisture transfer between the air and the grain.

Meanwhile, equilibrium moisture content (EMC) is the moisture content that the grain reaches when either adsorption or desorption processes stop. At this condition the grain is at a state of equilibrium with the air.

The surrounding air similarly has moisture or humidity that comes into equilibrium with the grain under static conditions. The state of moisture equilibrium reached by the air is the equilibrium relative humidity (ERH) of that air. The two states of equilibrium (EMC and ERH) determine the stability of cereal grains in storage. Temperature and relative humidity significantly affect the EMC of grains. Variety and past treatment or history of grains also affect their EMC but only slightly. Figure 2.9 to 2.12 show the predicted desorption EMC of some cereal grains under various temperatures and ambient air relative humidities.

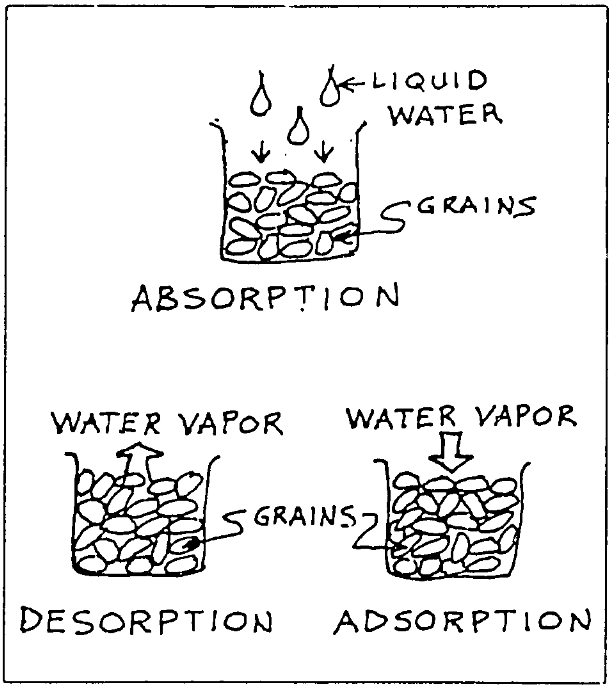


Figure 2.8. Absorption, adsorption, and desorption processes.

3. Respiration. - It is another biochemical characteristics of cereal grains. All living things respire. The two types of respiration among living organisms are **aerobic** and **anaerobic.** Aerobic respiration occurs in the presence of oxygen while anaerobic respiration occurs in the absence of oxygen.. In grains, aerobic respiration breaks down the carbohydrates into **carbon dioxide** and **water vapor.** The breaking down process producesheat.

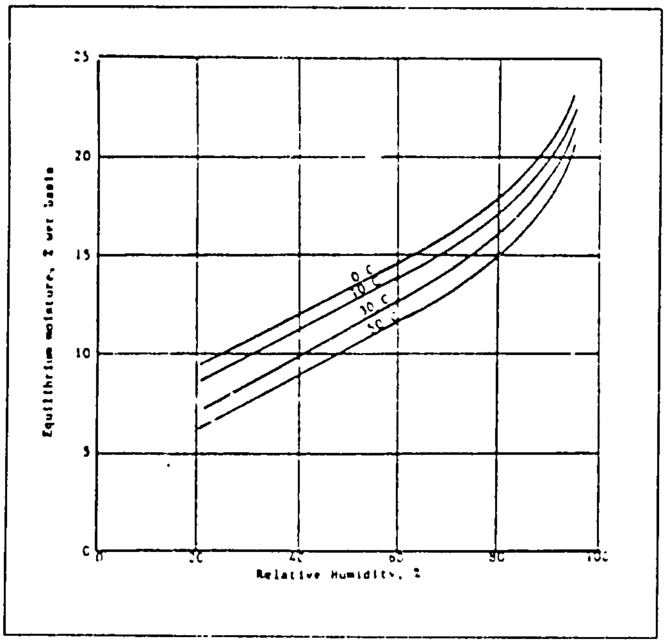


Figure 2.9. Desorption EMC of U. S. hard wheat.

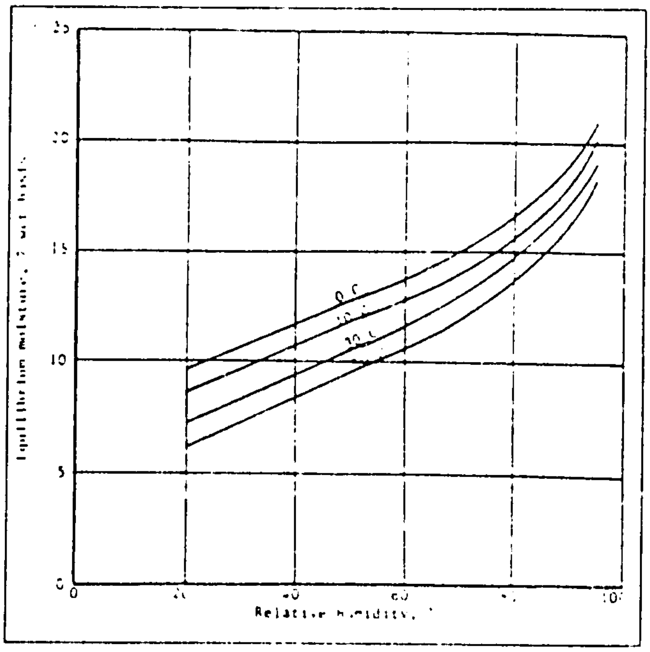


Figure 2.10. Desorption EMC of paddy rice.

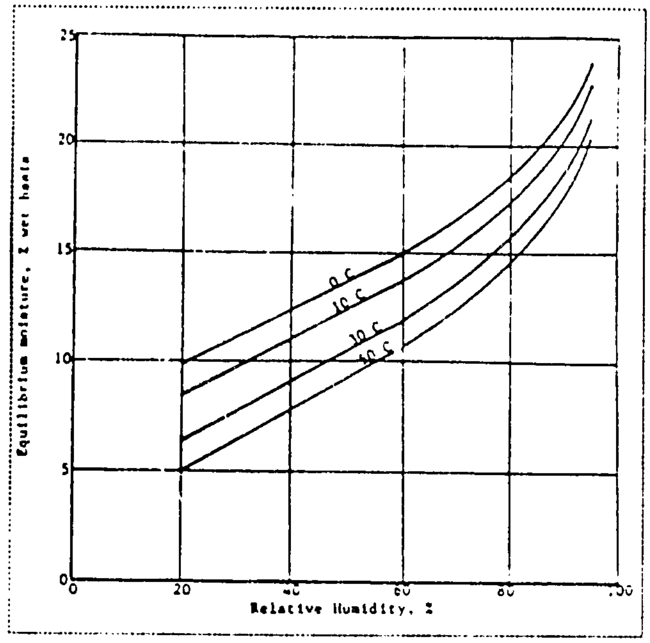


Figure 2.11. Desorption EMC of YD corn.

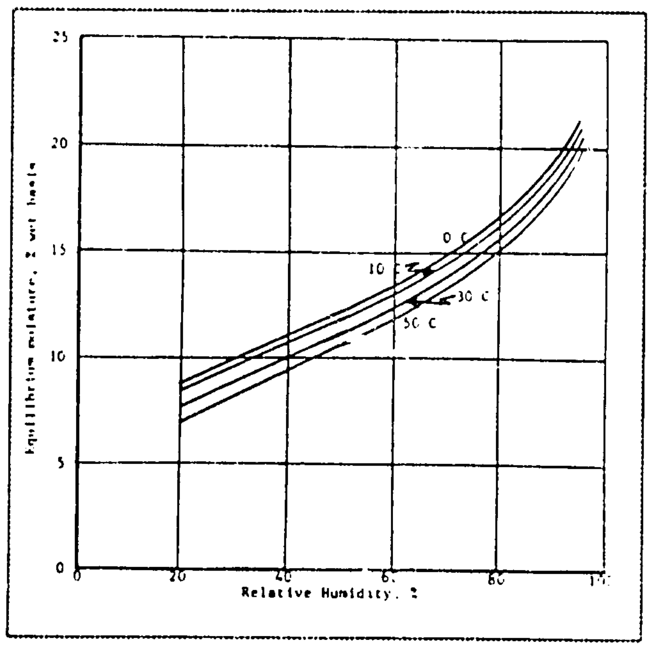


Figure 2.12. Desorption EMC of sorghum.

Aerating the grain removes this heat of respiration. However, studies show that the heat of respiration in damp grains is greater than that in dry grains. Measurements showed that the heat a cubic meter of dry grain produces in one hour is only about 6 calories. This is equivalent to the heat that will raise the temperature of 6 cubic centimeter of water one degree centigrade. A similar volume of wet grain generated 780 calories for one hour. This heat is equivalent to the heat that will raise the temperature of about 3/4 liter of water (780 cc) one degree centigrade. This is why dry grains store better and longer than damp grains before spoilage occurs. Other studies also show that the heat produced by microorganisms and insects is considerably greater than the heat grains generate.

Meanwhile, anaerobic respiration is a fermentation process that occurs without the presence of oxygen. It breaks down carbohydrates into lactic acid, acetic acid, or ethyl alcohol. The heat generated by the process is much less than the heat of aerobic respiration. Anaerobic respiration is not so much a concern of the grain storage manager as it is to the dairy farmer who uses anaerobic respiration to make silage. Silage is a very palatable roughage that dairy cattle and other ruminants eat as part of their daily feeding program.

Grains contain fats, proteins, and vitamins which are very essential in having nutritionally balanced food and feed stuff. Fortunately, these components of grains undergo little change under dry and cool storage conditions.

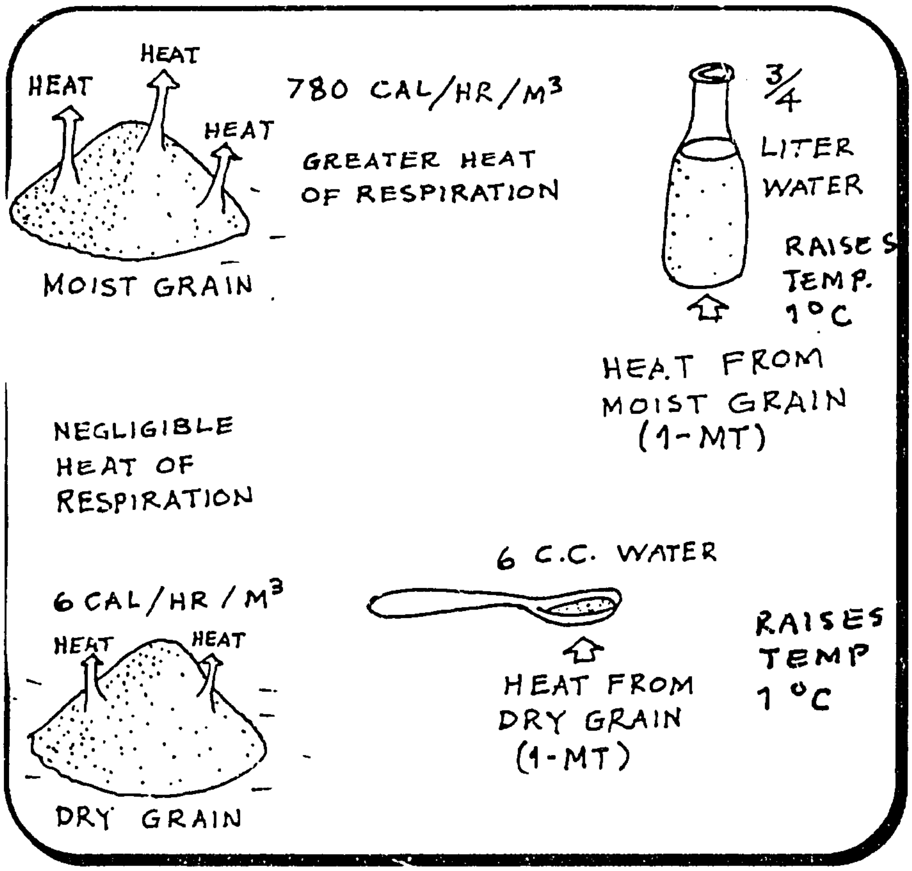


Figure 2.13. Illustration comparing the heat of respiration between dry and moist grains.

Table 2.1. Physical properties of cereal grains.

Kind of Grain	Wheat HRW	Shelled Corn	Rough Rice	Soybeans	Grain Sorghum
Test Weight per Bushel, Pounds	60	56	45	60	56
Bulk Density, Pounds per Cubic Foot (Average)	48	44.8	36.0	48.0	44.8
Bulk Density, Kilograms per Cubic Meter	770	720	580	770	720
Air Space or Voids in Bulk, Percent	42.6	40.0	50.4	36.1	37.0
Kernel Specific Gravity	1.30	1.30	1.11	1.18	1.22
Angles of Repose:					
(Emptying or Funneling), Deg.	27	27	36	29	33
(Filing or Piling), Degree	16	16	20	16	20
Average Coefficients of Friction on:					
Smooth Metal	0.340	0.447	0.479	0.368	0.372
Smooth Wood	0.294	0.302	0.530	0.312	0.294
Smooth Concrete	0.444	0.423	0.52	0.442	---
Specific Heat, Btu per lb-°F or Cal per gm-°C	0.39 - 0.51	0.43 - 0.53	0.22 - 0.26	0.47 - 0.49	---
Thermal Conductivity, Btu per Hr-Ft-°F	.087	.087	.050	---	---

Table 2.2. Conversion table from English to Metric System of measurements.

Cubic meters x 35.317 = cubic feet
Hectoliter x 0.1308 = cubic yard
Hectoliter x 3.5317 = cubic feet
Hectoliters x 2.83794 = bushel (2150.42 cu.in)
Kilograms x 2.20462 = pounds
Metric ton = 2204 pounds
1 U.S. gallon = 0.1337 cubic foot = 231 cubic inches
1 British Imperial gallon = 1.2003 U.S. gallon = 277.27 cu in
Liters x 61.023 = cubic inches
Liters x 0.035317 = cubic feet
Hectares x 2.47104 = acres
Square kilometer x 247.104 = acres
Square kilometers x 0.3861 = square miles

REVIEW QUESTIONS

1. Give the three major parts of a kernel of grain? What are their functions?

2. What physical property of grain affects its ability to slide on a surface?

3. What grain property prevents heat in the grain from dissipating to the atmosphere?

4. What is the significance of the percent of voids in a mass of stored grain?

5. What is the difference between bound and unbound moisture in grains?

6. Which forms of moisture affect the stability of stored grains?

7. Explain the difference between percent moisture content wet basis and percent dry basis.

8. Which type of respiration gives off more heat and why?

9. What causes most of the heating in stored grains?

CHAPTER 3

FACTORS AFFECTING GRAIN STABILITY

There are many factors that determine the stability of stored grains. The majority of these factors are external while others are inherent to the grain.

Each kernel of cereal grain is a small storage container. Just like any container it has the ability to protect its contents. Inside each kernel is an edible material that changes under the influence of its environment. The influence of the environment depends a great deal on the durability and property of the container. Some changes are beneficial other changes are detrimental.

The chart in Figure 3.1 shows the four factors affecting the stability of stored grains. It also shows the various forms of losses that fall under each category. Storage managers can minimize or control the adverse effects of these factors by proper handling, storage, and management of grain stored grains.

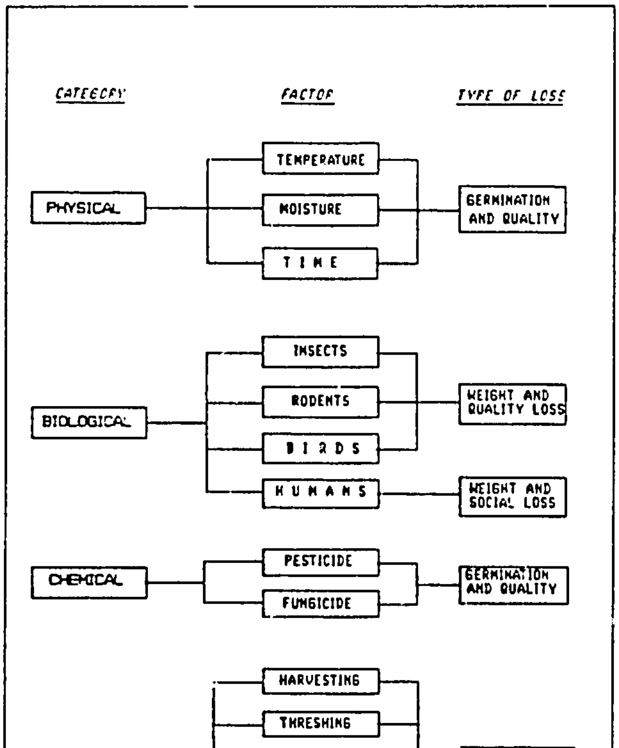


Figure 3.1. Factors affecting grain stability.

A. Physical Factors

Under this category, the three most important factors are <u>time</u>, <u>moisture, and temperature</u>.

1. <u>Time-</u> It is an important factor in all physical, biological, and chemical processes. Similarly, time affects the safe storage of any product. Grains that are safe to store for six months may not be safe to store in eight months. Also, grains that are unsafe for 6 months may be safe to store in 4 months. Figure 3.2 shows the effect of time and moisture on the production of carbon dioxide in stored wheat. Carbon dioxide production relates to the intensity of respiration and dry matter loss in grains.

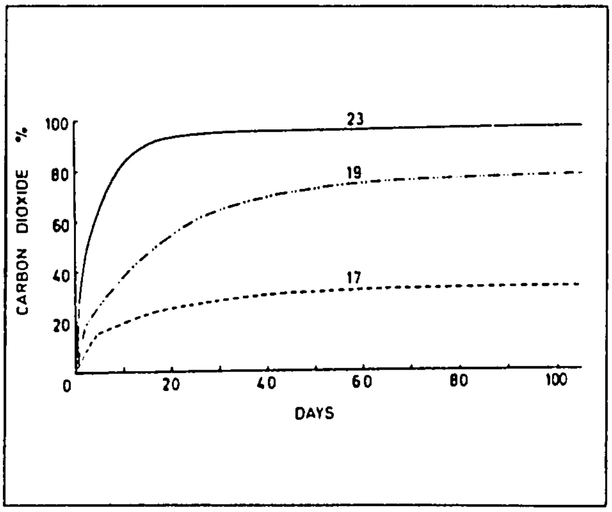


Figure 3.2. Carbon dioxide production in stored wheat at different moisture contents.

2. Moisture - Moisture is a major component of all agricultural products. The quantity of moisture in the grain usually determines how long it can stay in storage without appreciable loss of its quality or quantity. Also, grain moisture determines the relative humidity of the air in the inter-granular spaces in the grain mass. Relative humidity of 75% or more are favorable to mold growth and insect development. Insects subsist directly on grain moisture while molds rely on moisture from the air and not directly from the grain. Stack burning or grain caking are examples of spoilage caused by excessive moisture in grains.

3. Temperature - It is the third most important physical factor that affects the stability of stored grains. Normally, the ambient condition influences the actual temperature of stored grains. However, other factors such as insects and microorganisms also influence the actual temperature of the stored grain. As a rule, cool temperatures are ideal conditions for long term storage of grains. Figures 3.3 shows the allowable storage time of shelled corn as affected by temperature and moisture. The curves in the figure show that high temperatures drastically reduce the safe storage period of shelled corn.

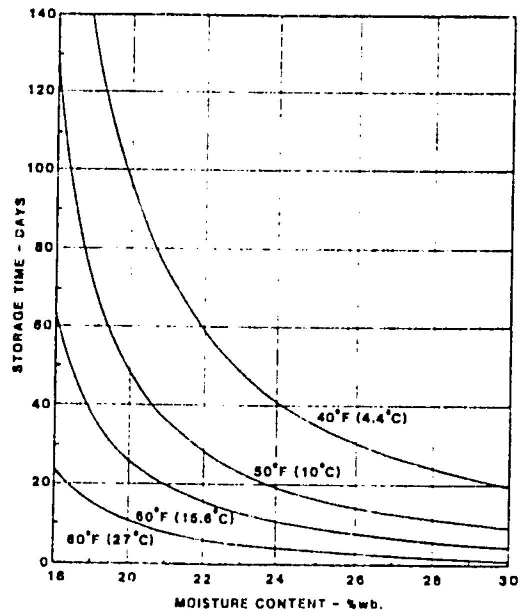


Figure 3.3. Effect of grain moisture and temperature on safe storage of shelled corn.

B. Biological Factors

Some very important factors influencing the stability of stored grains are biological in nature. These factors include microorganisms, birds, rodents, insects and to some extent humans. Some insects can penetrate the seed coat of grains while others feed only on broken grains. Meanwhile, molds and other microorganisms become a problem only under warm and humid conditions.

Another groups of biological factors affecting stored grains are birds and rodents. People in developing countries ignore birds and rodents because of cultural and religious reasons. Birds and rodents not only consume cereals but also contaminate them. Birds leave droppings which contain the *Salmonella* bacteria which causes food poisoning in humans. Rodents can transmit diseases to humans. Grains contaminated with rodent urine is unfit for food or feed purposes.

Figure 3.4 shows the effect of the presence of mold on the respiration rate of stored wheat at 35 °C. Mold contaminated wheat produced more carbon dioxide at two levels of grain moisture than mold-free wheat.

C. Chemical Factors

Pesticides and fungicides are two important chemical factors that influence the stability of stored grains. Pesticides are chemicals used to control most stored grain pests. However, high concentration of pesticide residues in grains can kill humans and animals. Low levels of pesticide residues can cause cancer in humans.

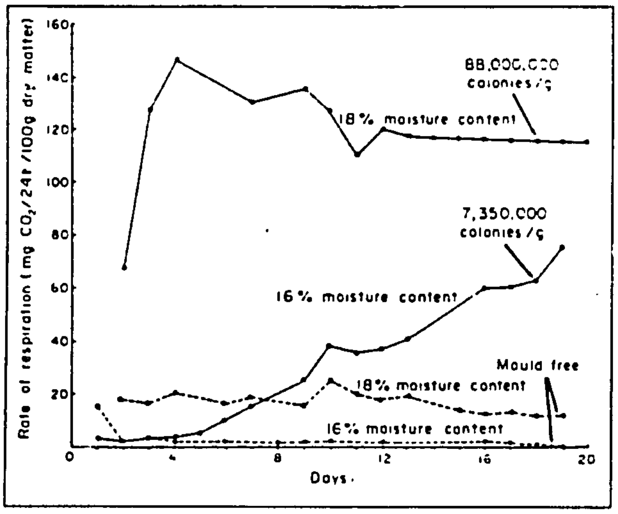


Figure 3.4. Influence of mold on the rate of respiration of stored wheat.

Pesticide-contaminated grains are unfit for human and animal consumption. The Environmental Protection Agency (EPA) in the United States monitors pesticide residues in food products. The EPA bans, in the United States, the use of many grain protectants still in use in other parts of the world today. However, it permits the use of a grain protectant like propionic acid for use on high moisture feed grains. Propionic acid is a fungicide that inhibits the development of fungi or molds. This fungicide is acidic which can corrode concrete and metallic materials. For this reason, farmers apply it only on grains stored in silos made of ceramics or lined with epoxy.

D. Technical Factors

Technical factors include all processes that the grain has to go through before and during storage. The technical factors are methods of harvesting, threshing, conveying, purity of grain, and storage conditions.

1. Method of Harvesting - It affects the storage stability of grains. Grains harvested by traditional methods are prone to damage by re-wetting in the field due to rain or morning dew. Re-wetted grains are susceptible to mold attack and internal crack development. Paddy rice is very susceptible to internal fissuring.

With internal fissures, it will easily break during milling. If the crop is relatively dry, some farmers shock or pile the harvested plant materials in the field. They pile it in convenient shapes and sizes before threshing. Under warm and humid conditions, molds can damage the grain and the seeds may sprout. Figure 3.5 shows the effect of piling newly harvested paddy and storing damp grain in bags on degree of deterioration. Field and storage fungi cause kernel yellowing or grain discoloration. Heaping newly harvested grain in the field poses no problems in dry climate provided grain moisture is 18% or less.

2. Method of Threshing - The threshing method used in detaching the grain kernels from the panicle has a significant effect on the percentage of broken grains. Some farmers still thresh grains either by beating or trampling by farm animals. However, increasing number of

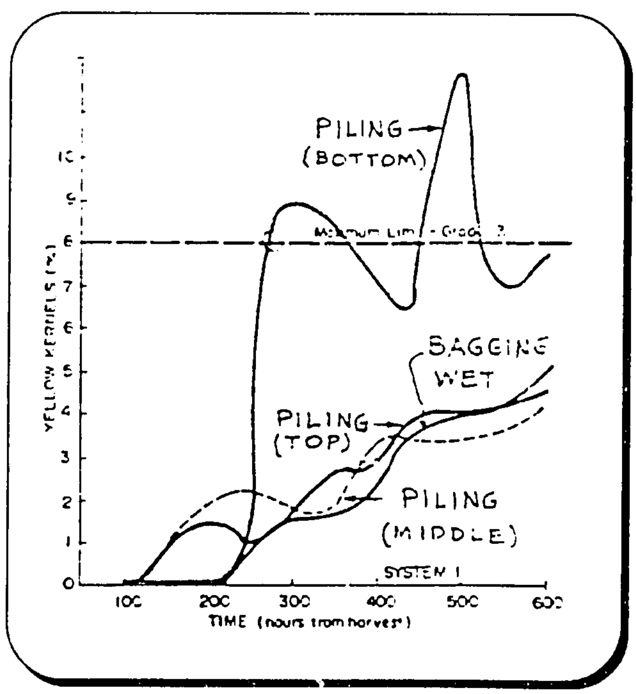


Figure 3.5. Effect of heaping and bagging wet paddy on extent of kernel discoloration.

farmers now use threshing machines because of the machine's availability at an affordable cost. Nevertheless, machines that have improper design and adjustment can cause excessive breakage in grains. Studies show that the threshing drum should not exceed a critical speed to avoid breaking the grains. We should bear in mind that stored grain insects can readily attack broken grains. Figure 3.6 shows the percentage of broken paddy due to threshing method and time of harvest.

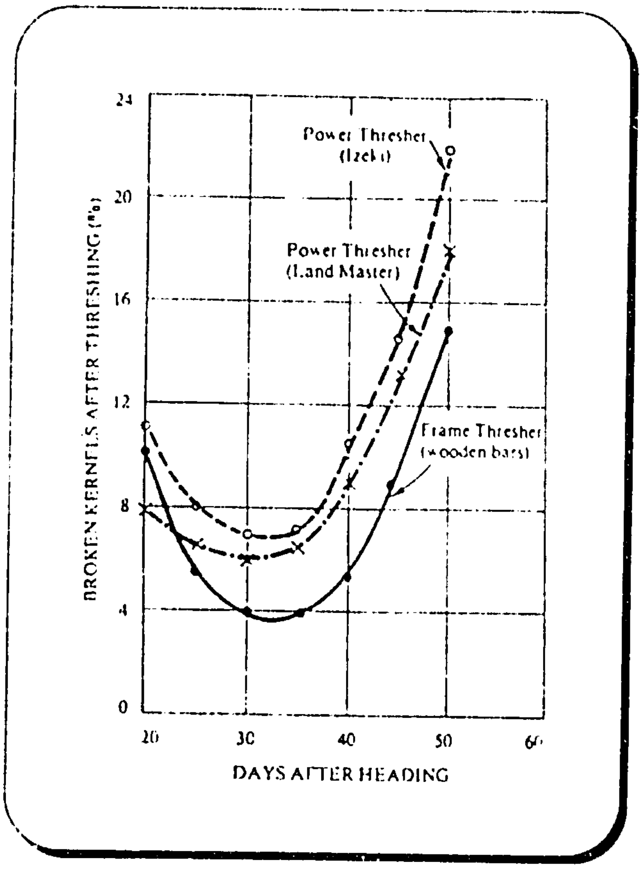


Figure 3.6 Effect of threshing method and time of harvest on the percent of broken paddy.

3. Method of Conveying - It has the same effect as the method of harvesting. Farmers and storage operators move grains with different conveying equipment. This equipment can impart enough force to crack or scratch grains. Scratched or broken grains are also prone to insect attack. A poorly designed and badly manufactured screw conveyor usually crack and break grains.

A belt conveyor is more gentle in conveying grains than either a screw or drag conveyor. Meanwhile, most of the pneumatic conveyors can cause high percentage of broken grains. This is because pneumatic conveyors require a very high air velocity to convey the grains. Hence, seed producers never use pneumatic conveyors in their seed processing operations. However, they are the best system for conveying flour and other meal products because they are self-cleaing.

4. Purity of Grains - It expresses the absence of foreign matters in a mass of grain. Grains containing high percentage of foreign materials and impurities are good environment for insects to multiply. Figure 3.7 compares the effect of storing clean wheat and wheat containing impurities on the development of stored grain insects. Also, the presence of thrash in a grain mass prevents the uniform flow of air during aeration. This usually results in hot spots and uneven grain moisture.

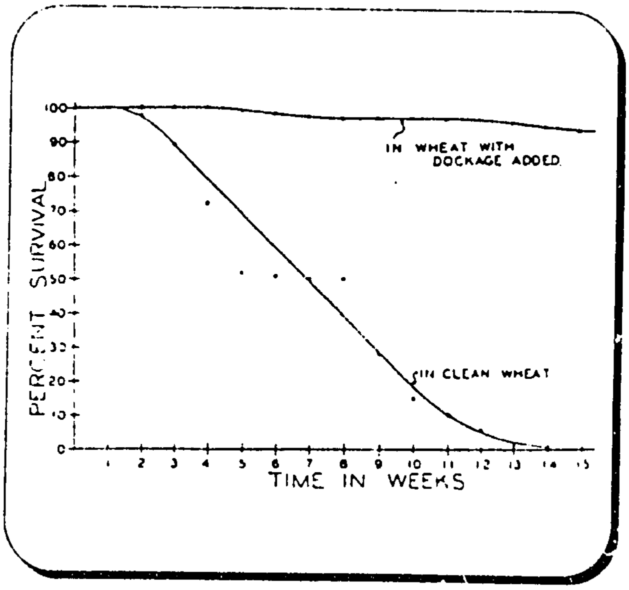


Figure 3.7 The effect of cleaning wheat before storage on degree of insect development.

5. Storage Condition - It is a very important factor affecting the stability of grains while in storage. A water-tight, rodent and bird proof building is an ideal place to store grains.

Furthermore, a properly designed and operated aeration system can prevent moisture migration in bulk grains. Aeration not only equalizes grain mass temperature but also cools the grain mass with appropriate ambient air condition.

This prevents the movement of inter-seed air by natural convection and possible grain spoilage caused by moisture translocation. Another example is the that light colored silo or structure reflect heat better that dark colored structures. This condition helps keep the grain mass temperature lower. Figure 3.8 shows graphically the phenomena of moisture movement in grain bins because of temperature gradients and subsequent grain spoilage. This pheromena is more severe when the ambient air humidity and temperature are at extreme conditions. Insects, mites, and molds will start to develop at the hot spots with high moisture.

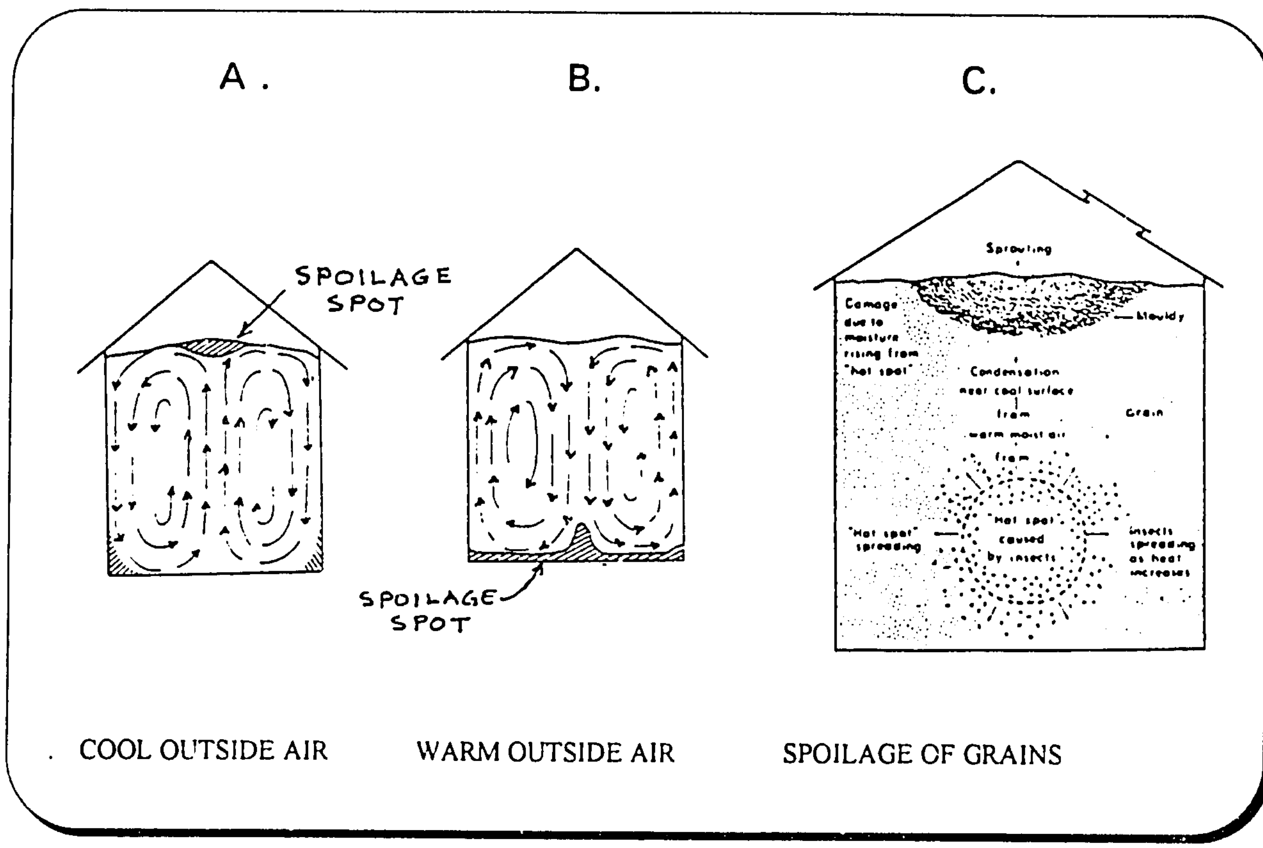
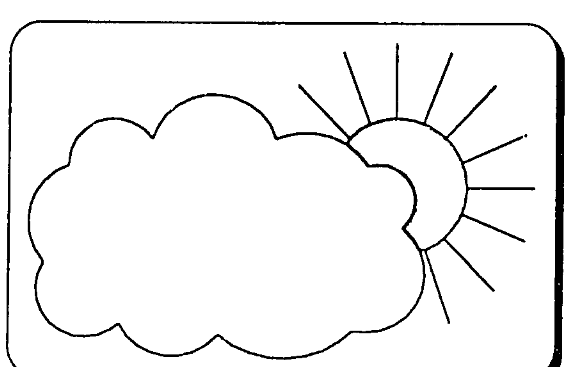
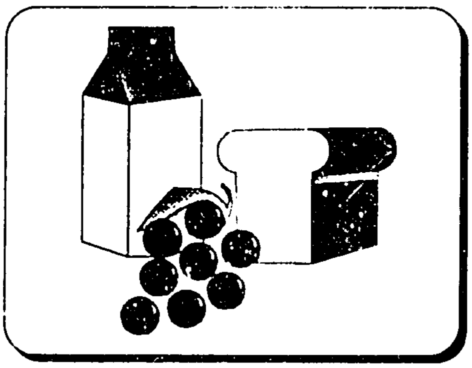


Figure 3.8. The two ambiental conditions (A) and (B) that trigger the phenomena of moisture migration in stored grains in silos and possible spoilage in a silo (C).



REVIEW QUESTIONS

1. *What are the four groups of factors affecting the stability of stored grains?*
2. *Why is a cracked grain more prone to insect attack than sound grain?*
3. *Give two good reasons why clean grain store better than unclean grains.*
4. *Explain the phenomena of moisture migration or translocation?*
5. *What is the consequence of moisture migration in stored grains?*
6. *How can a storage manager avoid having hot spots in bulk grain?*



CHAPTER 4

POSTHARVEST LOSSES

Postharvest losses of grains occur at various stages of handling from the farm to the consumer. The two categories of postharvest losses in grains are unavoidable and avoidable. Grain losses under both categories account for 10-20% of the world's total grain production annually.

A. Types of Postharvest Losses in Grains

Moisture and grain dust are bulk grain components that get lost in the system. They are the two most common forms of unavoidable losses that occur. Insect and mold damages are examples of avoidable losses. Some countries adopt a "no loss policy" in their grain storage management. In simple terms, "no-loss" policy does not allow changes in weight to appear in records once grain enters storage. Storage managers are responsible in maintaining the original weight of the stocks without allowance for shrinkage or losses. In a short term and high inventory situation, "no-loss" policy may be essentially correct. However, with low turnover and long term storage, a "no-loss" policy can create serious problems in grain storage management.

Official refusal to recognize that avoidable and unavoidable losses do occur is an administrative convenience. However, it does not eliminate the losses that actually exist. Hence, storage operators who are responsible for maintaining the inventory find some means of making up for such losses. They add extraneous materials or leave warehouse doors open to allow the grain to adsorb moisture from the humid ambient air. In some cases, they may short-weigh customers. They may also take other measures to make sure that the inventory always equals or exceeds the officially recorded weights.

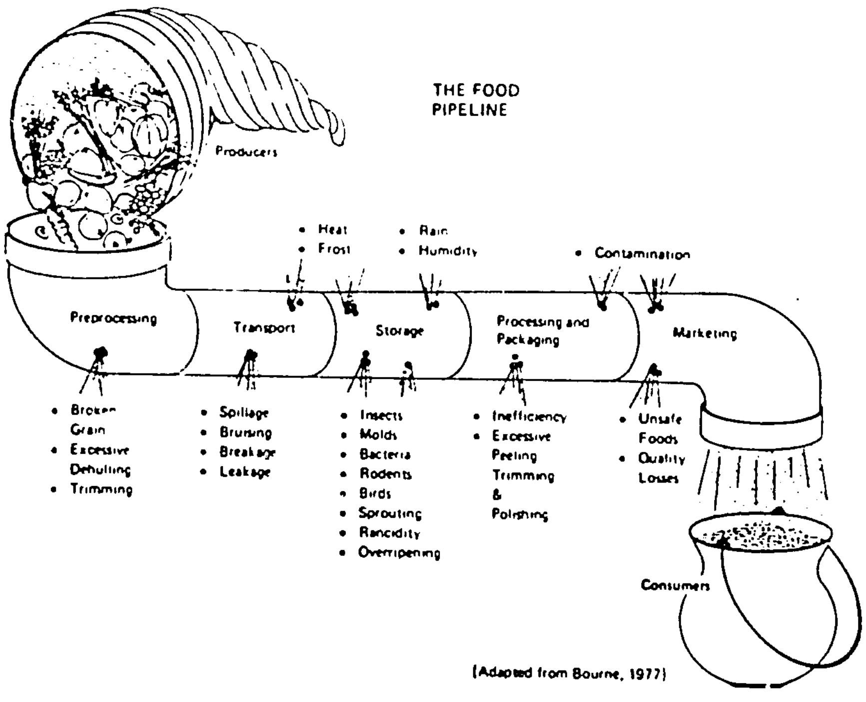


Figure 4.1. Points of leaks in the entire food pipeline.

However, by appropriating some funds for grain protection or for conservation programs, food agency administrators unknowingly recognize that avoidable losses do occur in stored grains. Therefore, the recognition of the various forms of postharvest losses in grains exist.. Therefore, taking some preventive and corrective measures are vital steps in minimizing losses.

B. Forms of Postharvest Losses

1. Physical Loss - It is a loss in the weight of grains. Factors contributing to this loss are: moisture evaporation, insect infestation, removal of dust and broken grains through cleaning and conveying operations. Table 4.1 is a guide in determining the final weight of a grain sample based on initial weight, initial moisture and reduction in impurities.

2. Quality Loss - It is a loss that molds and insects cause. Grain inspectors downgrade grains damaged by molds and insects. They classify them unfit for food or feed purposes. The fungus *Aspergillus flavus* causes the most serious quality loss in grains. It grows in the grain under warm and humid conditions. In their growth, the fungus produces aflatoxin which is a carcinogenic substance. This substance can cause liver cancer in humans and animals. It can impair the growth of heavy livestock and cause high mortality rate in poultry animals. Animal and human nutritionists set the maximum level of aflatoxin in food and feeds at 20 parts per billion. Grains and grain products containing aflatoxin levels above this limits are unfit either for human or animal use.

The process of detoxifying products containing the mycotoxin is neither practical nor economical. Contaminated grains are not even fit for use as soil conditioner. Aflatoxin is a major problem in the feed industries of many countries in Asia and Southeast Asia. This is mainly due to the very humid climate that prevails in the region almost throughout the year.

3. Biological Loss - The loss in the viability or germinating capacity of the seed grain is a biological loss. Heating the grains at temperature levels above 43° C during dying operations can destroy seed viability. Grains also lose their viability from insect and mold attacks. Some fumigants, such as methyl bromide, can also destroy the viability of seeds.

4. Nutritional Loss - It is a loss in the nutritional contents of grains during milling or processing. For example, the whitening and polishing processes in the milling of rice remove the B-vitamin contents. Washing the rice before cooking further removes the remaining vitamins in the grain. Similarly, flour milling removes the protein and oil-rich germ in wheat. An improperly operating milling system can cause the loss of bran and germ. Insects attack and remove the most nutritious portions of the grain. Heavily infested grains have lower nutritional value than wholesome grains.

5. Social Loss - Under-weighing and delivering poor quality grains and grain products is an example of social loss.. The product cost increases while satisfaction with the products made from poor quality grain diminishes. Consumers may suffer psychological problem after eating products containing insect fragments and residues. Many consumers may react by trying to substitute other food products for grains. Bad grain and unethical marketing practices cause the loss of goodwill and trust of consumers. The loss of trust and goodwill usually results in loss of business.

Releasing grain dust to the atmosphere also results in the loss of goodwill of the people around the grain processing and storage facilities. It can reduce the value of property and increase the incidence of respiratory problems. The degradation of the environment is another social costs that is not easy to calculate. All such effects will significantly add to the overall cost of grain and grain products.

Corruption is another form of loss under this category. Social scientists often blame low salary scales for the low standards of conduct in many developing countries. Another important source of the problem is the careless and indifferent attitudes of management.

Managers who do not establish fair rules of conduct nor show concern for high levels of performance from their employees are destined to fail. They will not be able to maintain grain inventories in a satisfactory manner.

6. Economic Losses - Economic losses are the monetary value of the above losses. Most postharvest studies base economic losses mainly on physical losses. Quality losses and the social losses surrounding grain handling and consumption are hard to assess or evaluate. They are very real in most societies in developing countries which need further research to accurately measure them.

REVIEW QUESTIONS

1. *What are the forms of postharvest losses in grains?*
2. *What is aflatoxin and its importance to grain users?*
3. *What microorganism produces aflatoxin?*
4. *When does aflatoxin occur in stored grains?*
5. *What are the most important cause of physical and economic losses in stored grains?*

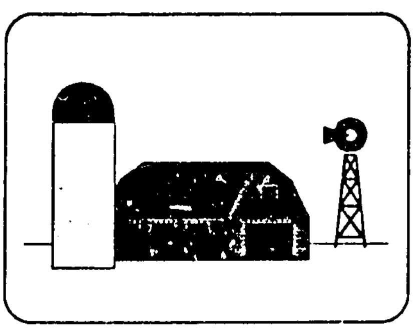


Table 4.1. Table sowing the effect of impurity and moisture on grain weight.

TABLE TO FIND FACTORS M & I TO CALCULATE DRY AND CLEAN GRAIN

——————> Final % Moisture

%	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	83.33	84.27	85.23	86.21	87.21	88.24	89.29	90.36	91.46	92.59	93.75	94.94	96.15	97.40	98.68	100
24	84.44	85.39	86.36	87.36	88.37	89.41	90.48	91.57	92.68	93.83	95.00	96.20	97.44	98.70	100	
23	85.56	86.52	87.50	88.51	89.53	90.59	91.67	92.77	93.90	95.06	96.25	97.47	98.72	100		
22	86.67	87.64	88.64	89.66	90.70	91.76	92.86	93.98	95.12	96.30	97.50	98.73	100			
21	87.78	88.76	89.77	90.80	91.86	92.94	94.05	95.18	96.34	97.53	98.75	100				
20	88.89	89.89	90.91	91.95	93.02	94.12	95.24	96.39	97.56	98.77	100					
19	90.00	91.01	92.05	93.10	94.19	95.29	96.43	97.59	98.78	100						
18	91.11	92.13	93.18	94.25	95.35	96.47	97.62	98.80	100							
17	92.22	93.26	94.32	95.40	96.51	97.65	98.81	100								
16	93.33	94.38	95.45	96.55	97.67	98.82	100									
15	94.44	95.51	96.59	97.70	98.84	100										
14	95.56	96.63	97.73	98.85	100											
13	96.67	97.75	98.86	100												
12	97.78	98.88	100													
11	98.89	100														
10	100															

PROCEDURE:

1. Locate moisture factor M
2. Locate Impurity factor I
3. Multiply both factors

Example: What will be the final weight of 100 kg of grain with 19% initial moisture and 6% initial impurity; if after drying and cleaning its final moisture is 14% and 3% impurity.

$$\frac{(\text{Factor M}) \times (\text{Factor I})}{100} = \text{CDGW (clean dry grain wt)}$$

$$\frac{94.19 \times 96.91}{100} = 91.28 \text{ kg}$$

Note: Both Tables apply only to quantities of 100 units. For other quantity use the following formula:

$$\frac{(\text{Factor M})(\text{Factor I})\ \text{MIGW}}{10{,}000} = \text{CDGW}$$

MIGW = MOIST IMPURE GRAIN WT.

CDGW = CLEAN DRY GRAIN WT.

Final % Impurity ↓ / Initial % of Impurity →	0	1	2	3	4	5	6	7	8	9	10
10											100
9										100	98.90
8									100	98.91	97.83
7								100	98.92	97.85	96.77
6							100	98.94	97.87	96.81	95.74
5						100	98.95	97.89	96.84	95.79	94.74
4					100	98.96	97.92	96.88	95.83	94.79	93.75
3				100	98.97	97.94	96.91	95.88	94.85	93.81	92.78
2			100	98.98	97.96	96.94	95.92	94.90	93.88	92.86	91.84
1		100	98.99	97.98	96.97	95.96	94.95	93.94	92.93	91.92	90.91
0	100	99.00	98.00	97.00	96.00	95.00	94.00	93.00	92.00	91.00	90.00

Initial % of Impurity ——

CHAPTER 5

PRE-STORAGE HANDLING OF GRAINS

Cereal grains are most vulnerable to damage while they are in the field awaiting harvest or collection.

A. Physiological Maturity

Prevailing weather conditions affect the maturing process of cereal grains. Warm and dry weather conditions enhance the maturing process of the grain kernels. For example, the maturing heads of rice and wheat turn yellow as the kernels ripen. The yellowing process of the grain is an age-old indicator when the crop is ready for harvest. However, a more reliable indicator when a grain crop is ready for harvest is its moisture content. The gradual decrease in the moisture content of the grain is part of its normal physiological maturing process. Its moisture content will continue to decrease as the weather gets dryer.

Some grains reach maturity when their moisture reaches the levels shown in Table 5.1. However, one should not allow the moisture to drop below this level to avoid shattering losses and attack by vertebrate pests. Shattering is a natural process where the mother plant disperses the mature seeds for the preservation of the specie.

Table 5.1 gives the normal moisture of most cereal grains at the time of harvest and their safe storage for one year. However, the moisture of wheat at harvest in Pakistan and other countries are lower than the values in the table. Farmers usually harvest paddy at moisture contents of about 22% to 24%. Meanwhile, ear corn has about 18% to 20% moisture content at harvest. Modern combines require a certain kernel moisture to minimize damage during combining operation. If the moisture is high, shelling will be difficult to accomplish since the individual kernels will not separate readily from the cob.

Researchers in India and the Philippines have identified many factors that affect the production and milling yields of rice. They found that the number of days after heading and the grain moisture at harvest affect both the production and milling yields. Figures 5.1 and 5.2 show the effects of both variables on milling and field yields, respectively.

Table 5.1. Optimum and usual moisture of grains at harvest and safe level for storage.

Percent Moisture Content, w.b.			
Cereal	Optimum	Usual	Safe
Barley	18-20	10-18	13
Corn	28-32	14-30	13
Oats	15-20	10-18	14
Rice	25-27	26-26	12-14
Sorghum	30-35	10-20	12-13
Wheat	18-20	9-17	13-14

B. Harvesting.

Manual harvesting of major cereal grains is the most common method in third world countries.. This is due to the availability of cheap labor and the lack of capital to purchase machines. Spreading the newly cut crop in the field for a day or two is a common practice in many countries to avoid grain spoilage. This helps the natural drying process of the grains.

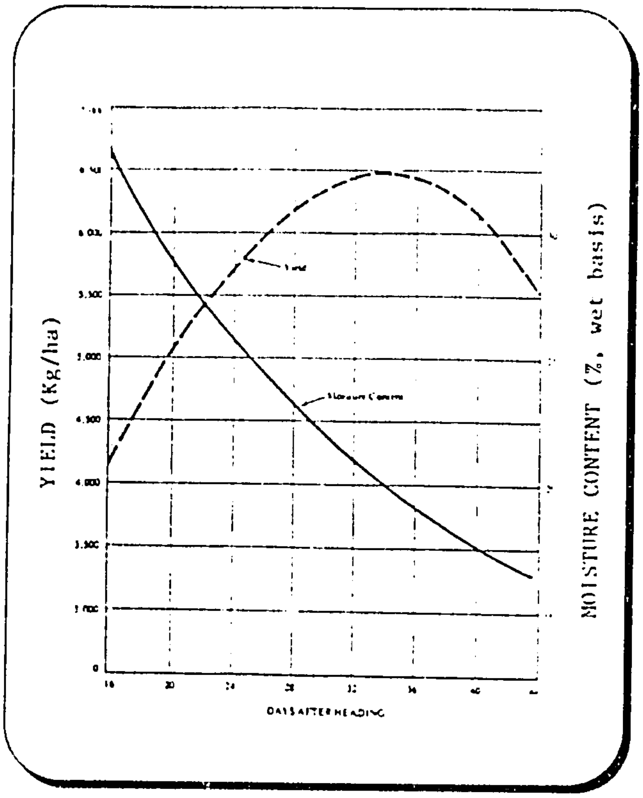


Figure 5.1. The effect of harvest time on grain moisture and field yields of rice.

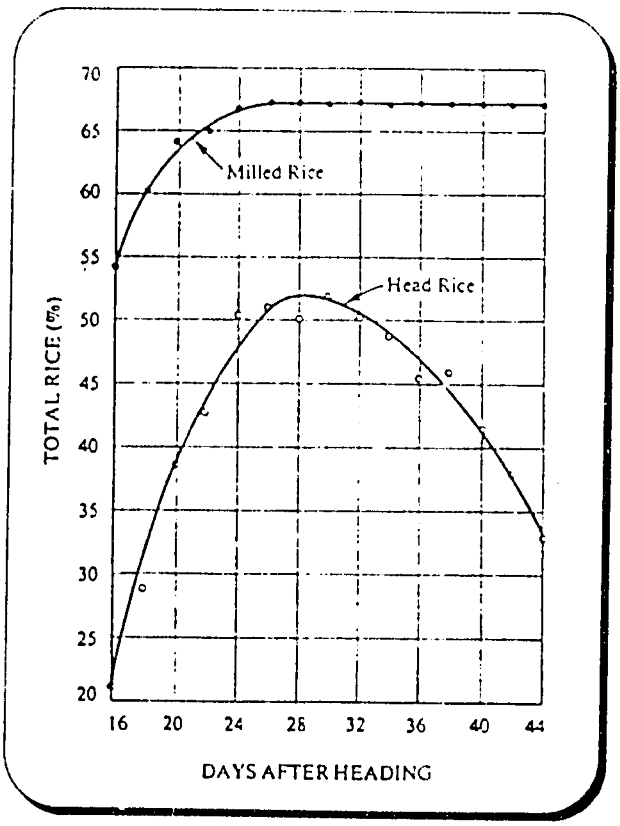


Figure 5.2. The effect of harvest time on the milling yields of rice.

process of grains. The cut materials may stay in the field for a few more days until the farmers collect and shock them in preparation for threshing. The shocking or heaping practices vary from place to place. Some heaps are rectangular in shape while others are circular (Fig. 5.3). In circular shocks the grain heads usually point towards the center of the pile. This is to conceal the heads from birds and other predators. However, one should not do this unless the grain kernels are relatively dry. If the grains are not dry enough, molds may start to develop and cause spoilage. This makes the practice of piling as the most vulnerable stage in the entire postharvest handling of grains most especially paddy rice. Heating can occur at this stage resulting in "yellow rice" or discolored grains.

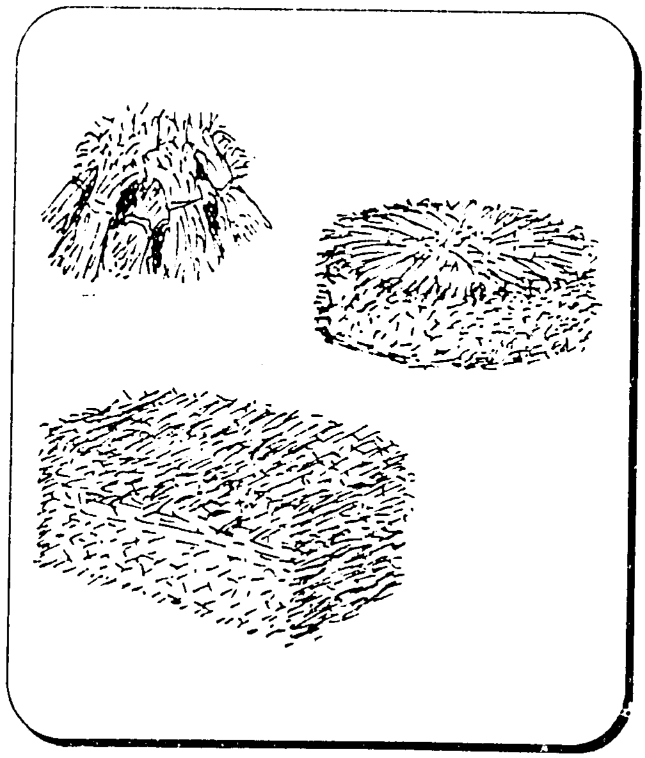


Figure 5.3. Shapes of shocks or piles in the field after harvesting.

However, mechanical harvesting of cereal grains has completely replaced manual harvesting in many countries. The large farming operations in these countries now use combines to harvest their cereal grains. The combine simultaneously cuts, threshes, cleans, and collects the grain all in one operation. Many combines have interchangeable cutting heads that allow them to harvest grains like wheat, rice, sorghum, maize and other cereal crops. The combining operation minimizes potential grain losses common to manual harvesting and handling of grains .

Aside from the combine, a small machine that can harvest both rice and wheat is the reaper. It is now gaining popularity among rice farmers in Asia. The machine cuts the plant a few centimeters above the ground and neatly lays the cut materials in rows. The gentle action of the reaper minimizes shattering loss. It also speeds up harvesting operation which is a big advantage in areas where there is a shortage of labor. The IRRI and the Peoples Republic of China jointly developed the rice reaper. They originally designed the reaper for mounting on a hand tractor. However, it underwent modification in Pakistan to mount on a small farm tractor for harvesting wheat. Figure 5.4 shows the original IRRI reaper while Figure 5.5 shows the modified version of the reaper developed in Pakistan.

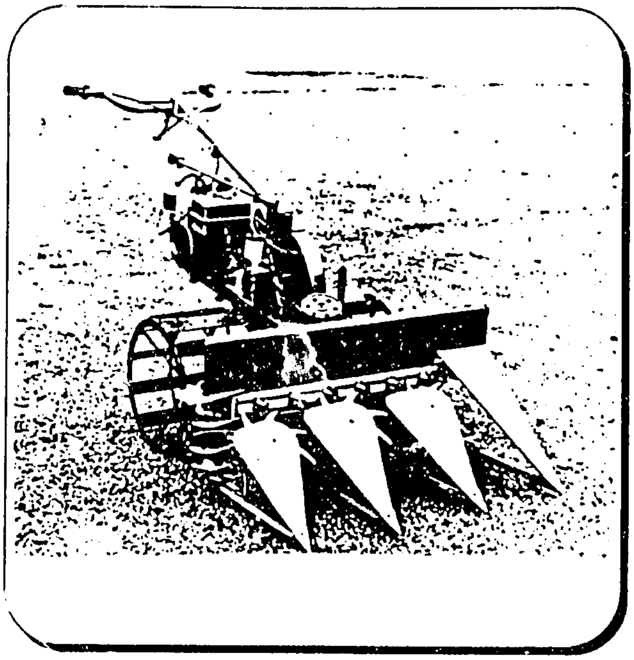


Figure 5.4. The original IRRI rice reaper.

C. Threshing

There are various methods of threshing grains like beating, trampling or the use of threshing machines. Each threshing method will have some amount of foreign materials present in the grain. The threshing operation usually incorporates dockage and impurities with the

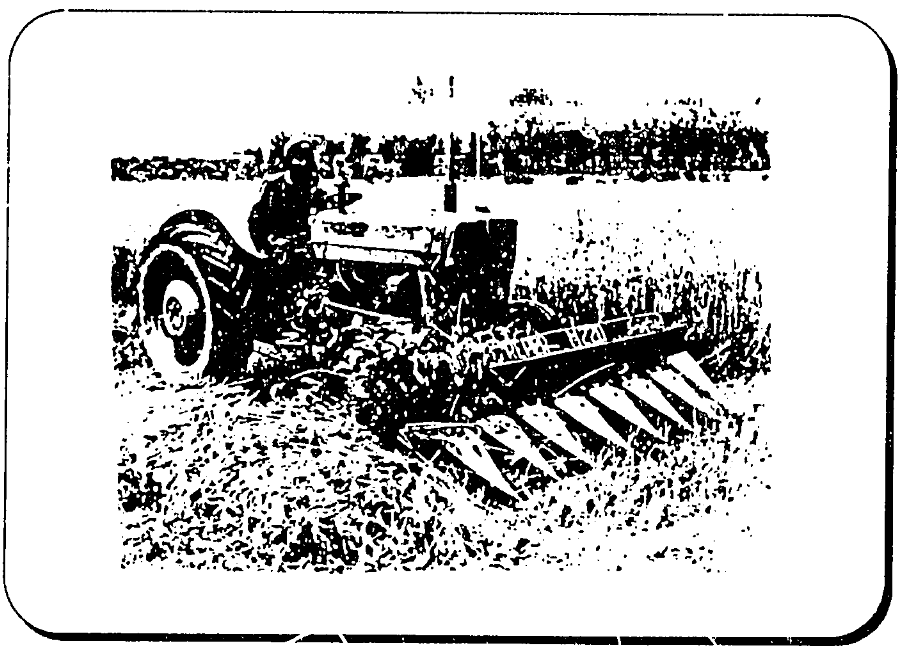


Figure 5.5. The modified reaper developed in Pakistan.

grain. It is very common to find more dust and small rocks in grains threshed traditionally than grains threshed with a machine. In Pakistan, it is common to have an admixture of grains and plant materials after threshing the grain. The method of threshing usually determines the extent of this problem.

A recent survey of the wheat crop quality in Pakistan showed that samples from combines contained about 3% broken grains. This percentage of broken grain was much higher than grain samples threshed by other methods. Improper adjustment of the machine, rather than design defect, is the probable cause of this problem. However, the advantage of harvesting the grain quickly to avoid field losses more than offsets the grain breakage problem. Also, mechanically threshed wheat usually contains chopped plant stalks. This is because mechanical threshers chop wheat stalks during the threshing operation. Most locally made machines have inefficient cleaning sections thus allowing finely chopped materials to mix with threshed grains. Nonetheless, the thresher and hand tractor are the two most important machines introduced in Asia in the last 20 years. With the thresher, farmers can now thresh grains in less time and effort than in the past using traditional methods. Both machines completely revolutionized the entire rice and wheat postproduction systems in Asia. They are simple to make and maintain. Figure 5.6 shows the principle of operation of a the famous "IRRI Axial Flow" thresher designed principally for rice. Meanwhile, Figure 5.7 shows the Pakistani version of a thresher designed for wheat. The IRRI thresher is now a common sight in Southeast Asia as much as the wheat thresher is now all over Pakistan.

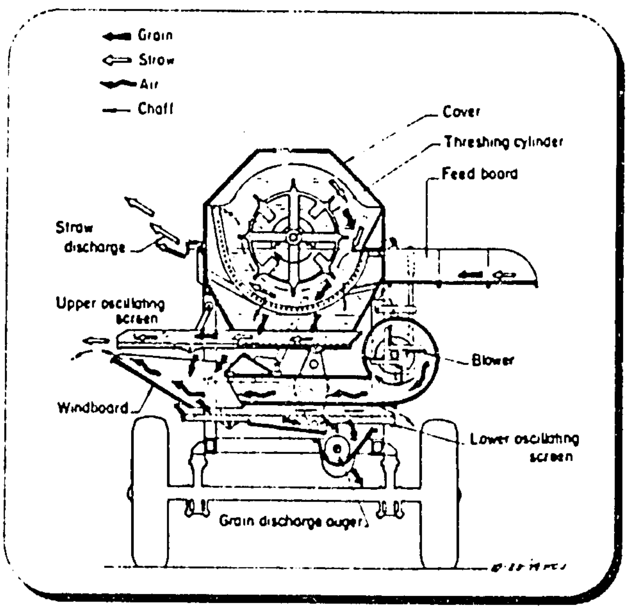


Figure 5.6. The IRRI rice thresher.

Figure 5.7. The Pakistan wheat thresher.

D. Collecting Grains

Grain collection involves grain handling, transporting, and temporary storage of grain before it enters normal marketing channels.

The collection point is usually close to the production area like village markets and small town market centers. They vary in size, shape, and handling technology. It is at this point where grain grading and classification can play a very important role in grain marketing. Through grading, traders can apply premium and discount pricing system. This system promotes the delivery of clean and wholesome grains by the producers and sellers alike. There are generally two methods of collecting grains in many countries., namely, traditional and modern.

1. Traditional System - Traditional collection centers in many developing countries are usually makeshift or temporary stores that grain merchant own or operate. They collect grains mainly using jute sacks or plastic bags. Tractor-pulled trailers or trolleys and flatbed trucks are the most common means of transport. The bag system allows the possibility of classifying and segregating grains of different grades and classes. However, there is no incentive to accomplish this under a single and fixed-price marketing system.

In many developing countries, itinerant grain traders buy grains from town to town and from city to city. They usually operate one or a number of trucks to transport grains from the farms to urban areas. Some may represent large family-owned companies that sometimes have integrated processing plants. These companies may own a flour and a feed mill. Others would have a combination of a bakery and biscuit or noodle factory.

In these countries, the government operates a food agency that procures and collects grain for buffer stock purposes. These agencies would own and operate a national network of procurement and storage centers. They store the grain as long as is necessary to make the grain available at controlled price throughout the year. These collection centers are usually larger than those owned by grain traders. Some use a completely bag handling system. Others may use a combination of bag and bulk methods of handling grains. However, the main system of handling grains in many countries is still the bagging method. This system will continue for many more years to come because of socio-economic factors. Some socio-economic factors in a country often perpetuate the bag system. Production methods and state of the economy are two examples of socio-economic factors affecting the grain collection, transport, and marketing system. Figure 5.8 shows a typical postharvest system in a developing country using either bag or bulk handling system.

Most Economists agree that the bag handling and storage of grain is more costly than bulk grain system. While this is perhaps true, most of the developing countries are not ready for the change-over in spite of the expected advantages of bulk grain system. To effect the change, they need to adopt bulk handling system gradually from production to marketing. Pakistan has taken a giant stride towards bulk handling system. For the last three years the food agencies have tried successfully a method of bulk grain collection and transport. It has shown great potential for adoption. The system uses portable grain handling and transport equipment shown in Figure 5.9. The whole bulk system includes a newly renovated 50,000 silos in the Punjab.

The adoption of this type of technology will take place gradually and over a long period of time. Nonetheless, technological changes must occur for a nation to progress. They must keep pace with the rest of the world if they hope to raise the quality of life of their people.

2. Modern Grain Collection System - The **Country Elevator** is a typical grain collection center in many Western countries. Farmer cooperative societies (Coops) usually own and operate country grain elevators. Farmers usually bring their grain in bulk directly from the combines in the fields. A COOP may either buy the grain from a member or stores it for the farmer at a special rate. The grain will move from the country grain elevator to grain regional terminals or directly to food or feed processing plants. Grain elevators usually have complete grain cleaning, drying, and grain

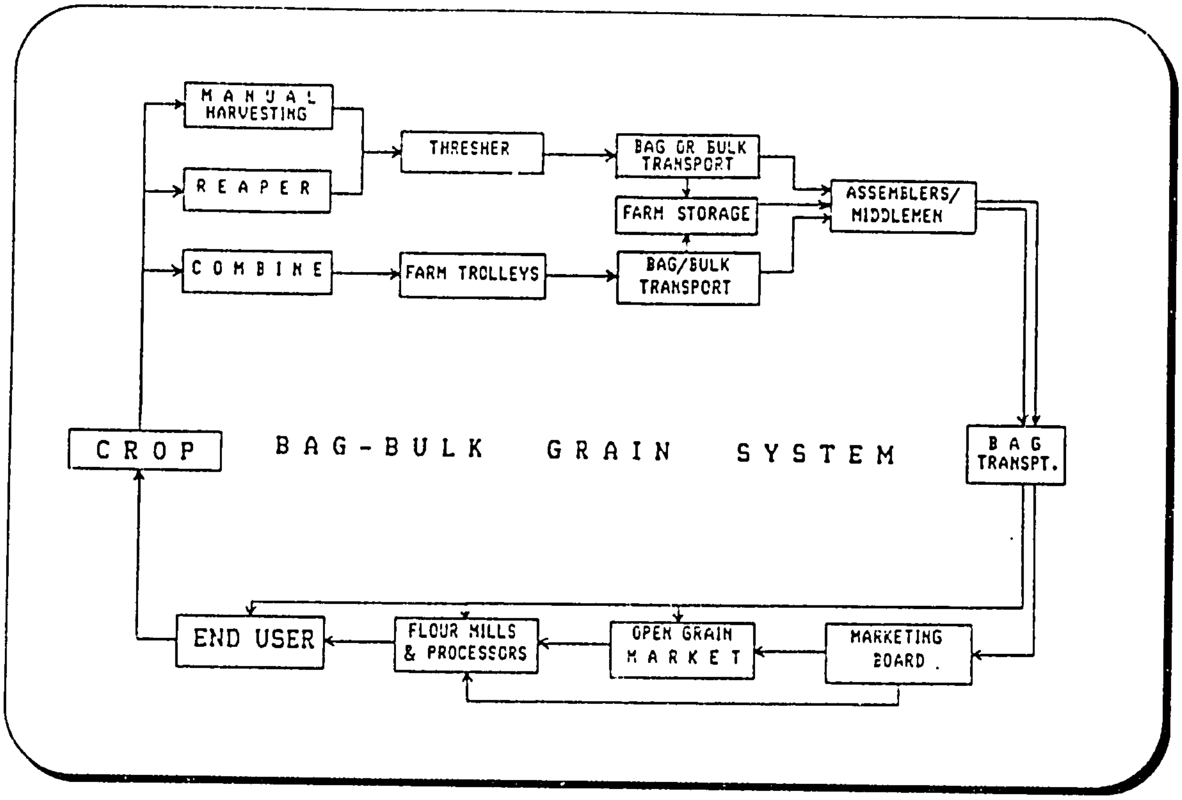


Figure 5.8. Typical postharvest system in many developing countries.

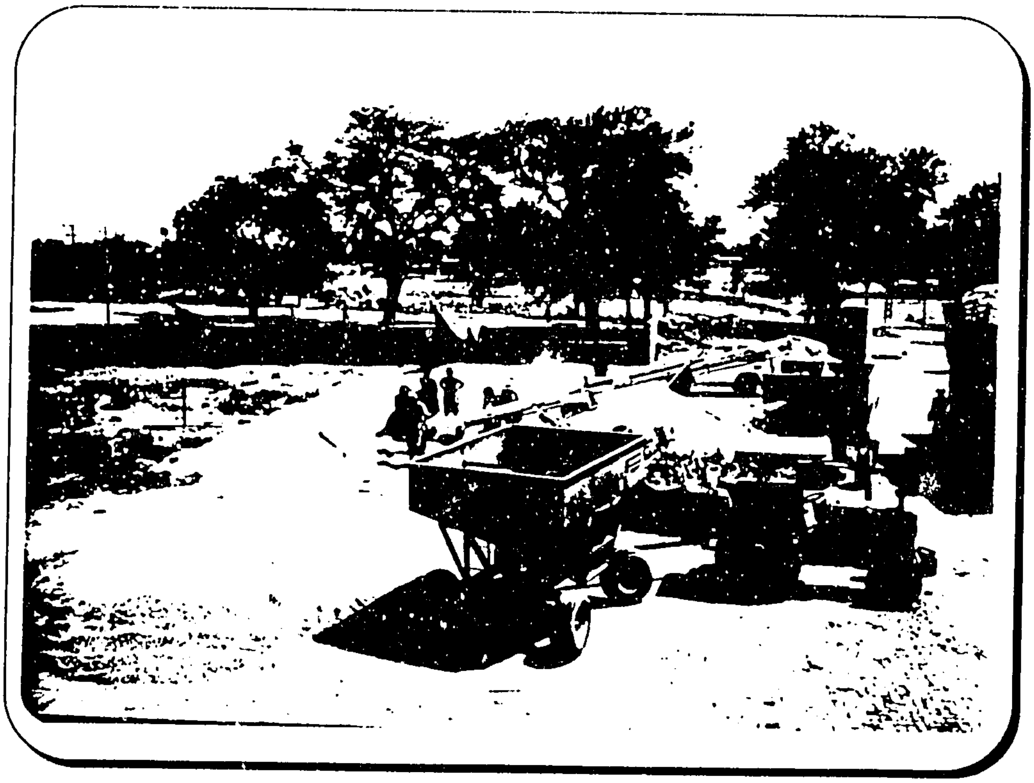


Figure 5.9. A bulk collection method Kansas State University recently introduced in Pakistan under a USAID in Pakistan.

protection facilities. Managers have the option of cleaning, blending, and conditioning the stored grain to meet quality standard for a given market.

E. Grain Receiving System

Grain receiving activities include weighing, recording, conveying, cleaning, and assembling operations. In most developing countries, these operations are predominantly labor-intenve systems. In contrast, these operations are all mechanized in developed countries. Bulk grain move directly from the combines to the nearest collection point such as a grain elevator. A grain receiving system normally involves weighing, grain testing, pre-cleaning, and drying of a grain consignment.

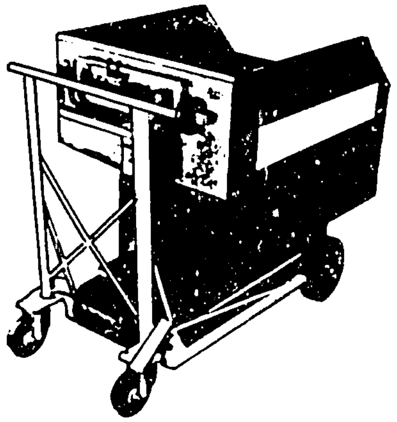


Figure 5.10. A portable bulk scale used for field weighing of wheat.

1. Weighing - Grain traders in developing countries use simple portable platform scales of various sizes capable of weighing small to medium size batches of grains. Some have access to a truck scale which greatly facilitate the weighing operations. A truck scale allow the weighing of either bag or bulk grain. In instances where there is no truck scale available, they randomly check about 10% of a consignment of bagged grain. A truck scale or bulk weighing system is an absolute necessity in a completely bulk grain handling system. In many countries, the weighing and grain testing operations are the usual bottlenecks in the entire grain receiving operation. Many grain merchants trust their own scales more than the truck scales of a government food agency.

Fortunately, the portable bulk scale in Figure 5.10 offers an alternative system of weighing bulk grain in small quantities. It has good potentials in introducing a completely bulk handling system in developing countries. The portable bulk scale is simply a platform scale with a bin that holds about 375 Kg of grain and has a discharge gate at the front end.

2. Grain Testing - The testing of any grain shipment or consignment is a fundamental procedure required in any grain handling, storage, and marketing operations. This is an operation that allows the classification and sorting of grains for storage management and marketing purposes. Grain testing includes the drawing of grain samples and determining its physical and other characteristics (see Chapter 10 for a more detailed discussion).

3. Pre-Cleaning - Pre-cleaning involves the removal of foreign matters by scalping, screening, or by aspirating. Pre-cleaning is a very important step that affects grain dryer performance, characteristics of grains, and their market value. The removal of foreign materials from grains have the following advantages:

- Reduces the energy required to dry a batch of grain.

- Removes materials that could cause grain deterioration in storage.

- Removes materials that could damage grain handling equipment.
- Reduces the required space for storage
- Increases the market value of the grain.
- Improves fumigation effectiveness.

Grains and foreign materials differ in their physical properties. The difference in their physical properties permits their separation by using grain cleaning devises. Grain cleaners use one or a combination of the differences in physical properties to cause the separation process. The common physical properties used in grain cleaning and receiving are size, shape, terminal velocity, specific gravity, and magnetic property. In a pre-cleaning operation the first three properties are the bases for separating foreign materials from the grain.

a. *Size* - Sizing permits the use of sieves or screens to separate large materials from fine particles. Grain cleaners with different sizes of screens can separate small seeds and dust from grains. Some cleaners have wire mesh sieves while others have perforated sheet metals. Perforated sheet metals are more durable than wire screens and have perforations of different shapes and sizes. This principle of separating different materials is very common in field equipment such as threshers and combines. It is also very common in grain processing plants.

b. *Terminal velocity* - Winnowing or blowing separates light materials such as chaff and dried leaves from grains. An aspirating machine separates light materials from a stream or layer of grain. Light materials have lower terminal velocities than heavy materials. This means that the air stream will pick up the light materials from heavier ones by using slower velocity of air. A cyclone makes use of this principle of separation.

c. *Shape* - This property allows the separation of grains of different shapes or lengths. Perforated sheet metals can perform separation by size. Most grain cleaners with rotating cylinders or oscillating screens use this grain characteristics to remove foreign materials from the grain mass. The grain cleaners in Figure 5.11 and 5.12 are but a few of the many pre-cleaners available in the market today.

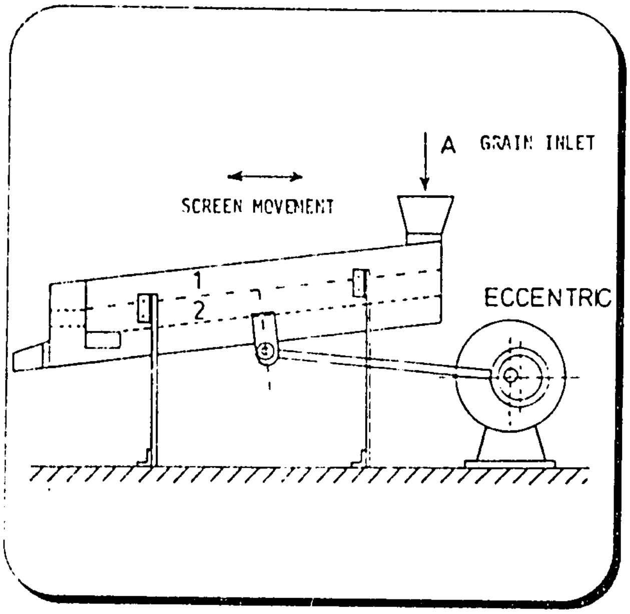


Figure 5.11. A simple paddy pre-cleaner.

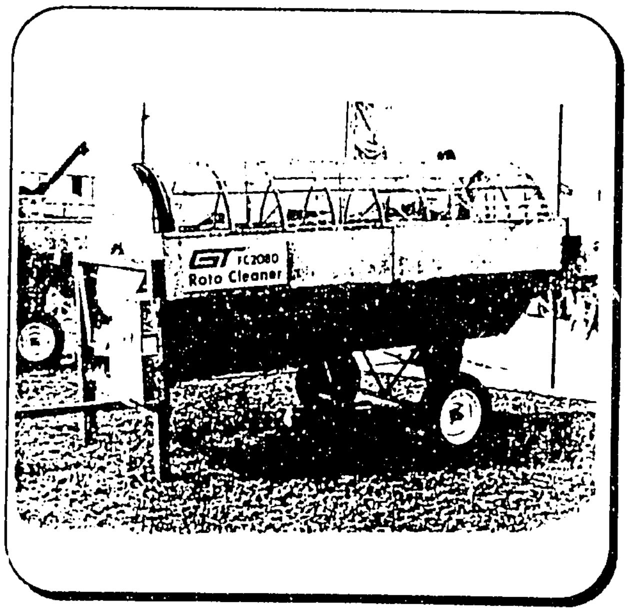


Figure 5.12. A portable grain cleaner with two rotating screens.

4. Grain Drying - Drying is the process of removing the excess moisture content of agricultural products to prevent spoilage. Most cereal grains contain excess moisture at harvest. Heaping moist grains is a bad practice because of possible heating. It is much better to spread moist grain on a floor or mat than heaping it. This will allow any heat of respiration to dissipate to the atmosphere. Grain heating is a sign of respirative activity and the subsequent grain deterioration. Chapter 6 will discuss grain drying in more detail.

5. Inventory control - Inventory control is a system of recording and accounting stocks. This is a very important activity during procurement, storage, and marketing operations. The accurate accounting and control of stocks determines the success of the entire business. In most countries, manual recording and accounting is still the standard method of inventory control. However, many countries are now gradually entering the computer age with the use of Personal Computers.

Along with the computers are inventory control programs that can eliminate the tedious job of manually entering numbers in record books. Accountants can rapidly enter and get accurate inventory of incoming and outgoing stocks. They can minimize human errors which is common in manually entering and calculating numbers.

REVIEW QUESTIONS

1. *When is a cereal grain mature?*

2. *What is the significance of the excess moisture of grains?*

3. *Give the two machines that revolutionized the postharvest handling of grains in Asia.*

4. *In what stage in the entire postharvest system is the grain most vulnerable to mold damage? Why?*

5. *Why is bag handling system still popular in many developing countries?*

6. *What are the benefits of pre-cleaning grains before storage.*

7. *Give three bases used to separate grain from foreign materials.*

8. *Enumerate 3 important reasons for cleaning grains before storage.*

9. *Give 3 physical properties of grain that pre-cleaning operations use.*

CHAPTER 6

GRAIN DRYING AND AERATION

Grain drying and aeration are two distinct grain handling operations. Grain drying removes the excess moisture in grain while aeration removes the excess heat in stored grain.

Grain drying and aeration are two distinct grain management operations but seem to have a lot of similarities. They both require similar equipment such as fans, air ducts, and control systems to move air through the grain mass. The air they move have certain psychrometric properties that performs a specific purpose. While drying uses heated air to remove the excess moisture in grains, aeration generally uses cool to remove the excess heat in the grain mass. Both operations are means of preserving stored grains.

A. Grain Drying

1. Principle of Drying - In technical terms, drying is the simultaneous transfer of heat and moisture. Heating a product raises its temperature and increases its vapor pressure which results in the evaporation of the moisture. Most of the moisture in cereal grains is in vapor form. Any moisture in liquid form in the grain evaporates very quickly during the initial stages of drying. Grain drying calculations normally neglect this initial drying period. Drying experts recognize two major stages in grain drying. These stages are constant rate and falling rate periods. Grain drying during constant rate period removes the moisture from the outer layers of the grain. As drying progresses, the moisture in the inner layers gradually move towards the surface of the grain (Figure 6.1).

The rate of moisture movement from the core to the outer layers decreases as the grain gets dryer. The decrease in moisture movement occurs during the falling rate period. It is more economical to terminate the drying operation at the end of this period. This moisture movement continues until the core of the grain dries to a certain level. The graph in Figure 6.2 shows the constant rate and falling rate periods in grain drying.

Heating hastens up this moisture removal. However, the rapid removal of moisture in grains usually results in internal cracks or stresses in the structure of the grain. This makes the grain susceptible to breakage during subsequent handling and milling. Drying the grain in 2 to 3 stages avoids the potential problem of cracking in paddy rice or case hardening in shelled corn. Giving the grain a rest period between drying stages allows the moisture in the grain to equilibrate or re-distribute thus enhancing the moisture removal during the next drying stage.

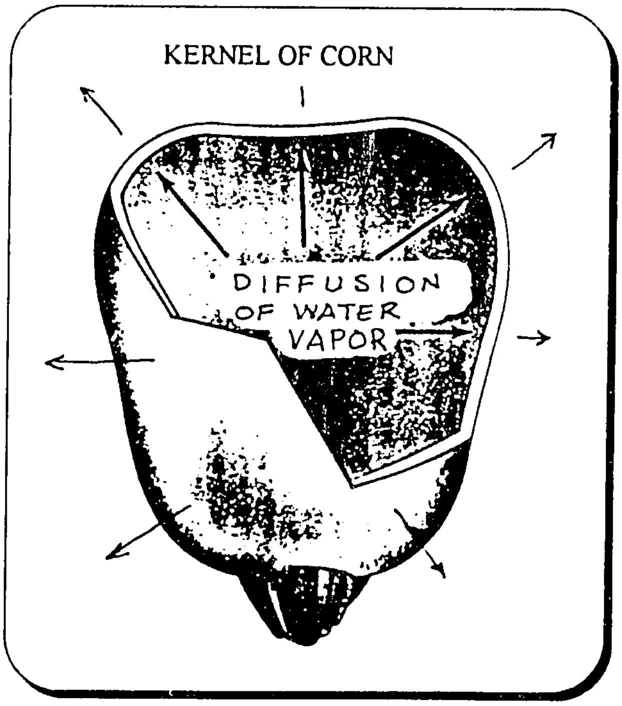


Figure 6.1. Water vapor movement in a corn kernel.

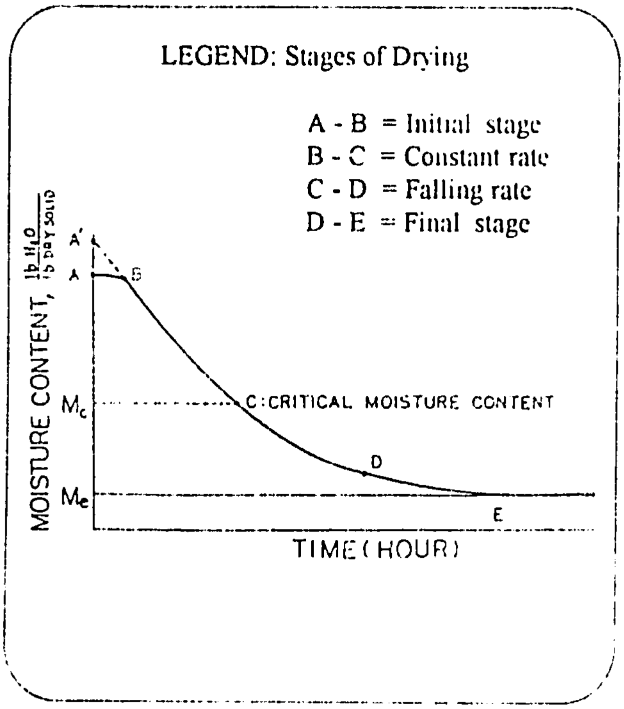


Figure 6.2. The stages in grain drying.

2. Traditional Drying Practice - Traditionally, farmers dry grains by spreading them under the sun. Most people call this method sun drying others wrongly call it solar drying. Solar drying is an indirect method of drying a product with the heat of the sun. Solar drying requires a method of first collecting solar heat before using it for drying. Meanwhile, sun-drying is a direct method of drying grains (Figure 6.3).

Sun-drying is a very popular method of drying grains in developing countries because it is simple and cheap. One has only to find an open space like concrete floors or pavements to spread the grain under the sun. However, there are some risks involved in sun drying like grains getting rewetted, predators, and theft. Sun drying usually results in the incorporation of foreign materials such as dirt and small rocks with the grain.

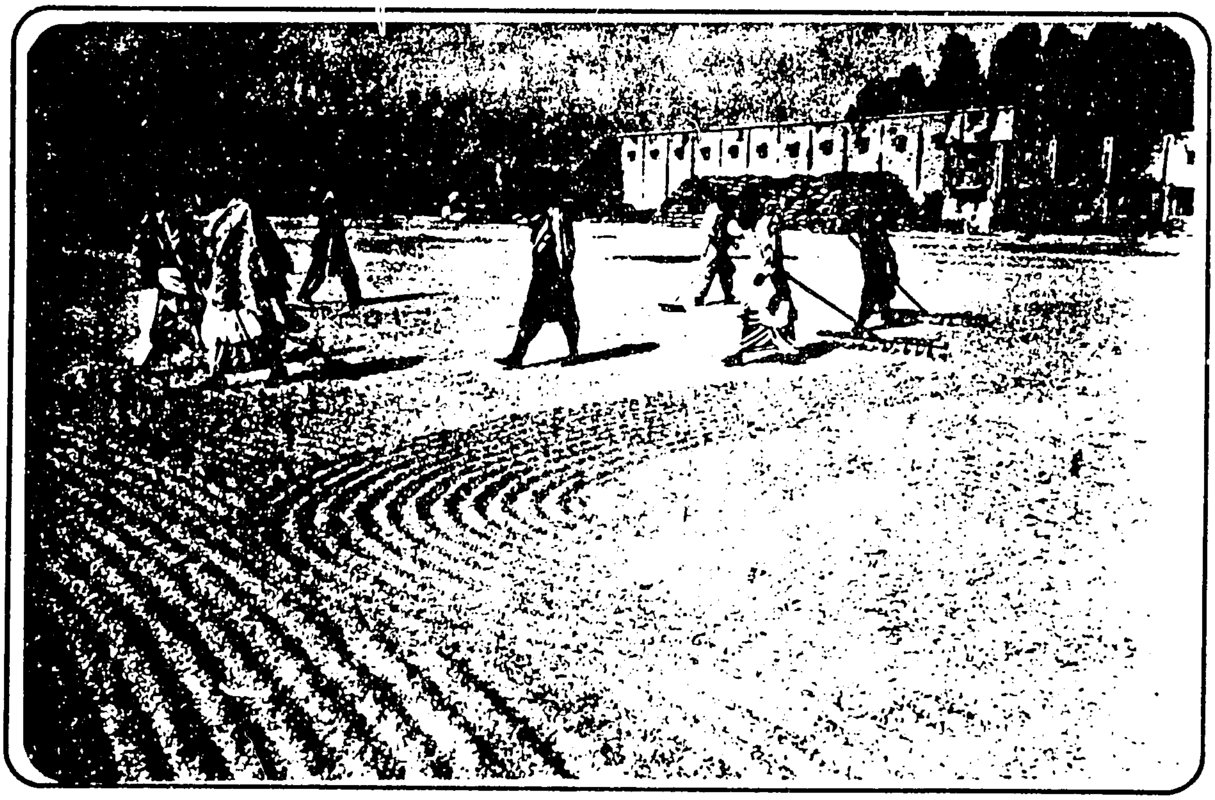


Figure 6.3. A typical sun-drying operation of paddy in the Punjab, Pakistan.

There are two important techniques to remember when sun drying grains. The **first** is to keep the grain layer no more than 4 cm thick for faster drying. The **second** is to stir the grain regularly at half hour intervals. Both techniques hasten the drying process and also results in a more uniformly dried grain. A more uniformly dried paddy rice results in better milling yields reflected by less brokens and more whole white rice. Under a normal sunny day, it is possible to dry paddy from 24% moisture down to 13% in one day using the above technique. Figure 6.4 shows the effect of stirring technique on the milling yield and drying rate of paddy rice.

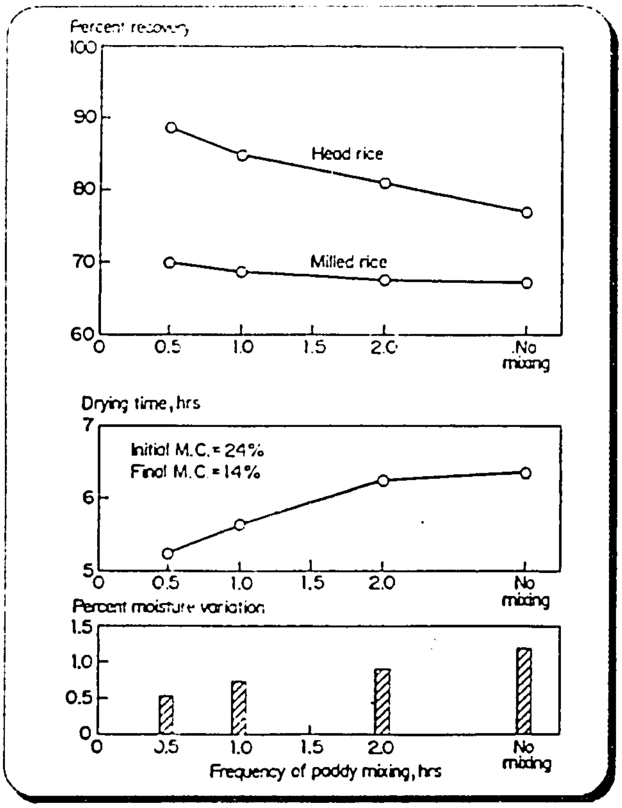


Figure 6.4. The effect of stirring on drying and milling yields of rice.

In the case of wheat, its moisture content at harvest ranges between 9 to 11 percent. At this level, the grain requires no further drying unless it re-adsorbed moisture while still in the field. While sun drying is simple and relatively cheap, the quality of the dried grain is not always desirable because of the uncertainty of weather conditions. Because of this uncertainty, the use of artificial means of drying grain offers better control of grain quality.

3. Artificial Drying - Artificial or mechanical drying is the use of heated air to remove the excess moisture in cereal grains. With artificial grain drying, plant managers have a better control of the entire grain processing operation. For example, they can avoid potential delays in rice milling because of bad weather conditions. Artificial drying allows managers to dry grain to meet their production outputs with better control of grain quality. Similarly, a production manager can harvest his crop ahead of time to allow early land preparation for the next crop.

4. Components of a Grain Dryer - Artificial grain dryers have five basic components regardless of their size and configuration. These parts are the heating system, fan, frame, prime mover, and controls.

- Heating system - It simultaneously raises the temperature of the drying air and the grain. Heating increases the vapor pressure of the grain moisture (unbound water) resulting in moisture removal. The two methods of heating the air are direct and indirect. Both methods require a fuel burner or furnace to generate heat. Commercial drying operations normally use gas or liquid fuels.

To save on drying costs, some operators use cheaper sources of energy, like agricultural wastes products (biomass) and other forms of energy (solar heat). A simple biomass furnace (Figure 6.5) uses agro-wastes materials (rice hulls) and wood chips. Biomass furnaces have potential use in many farm level drying operations.

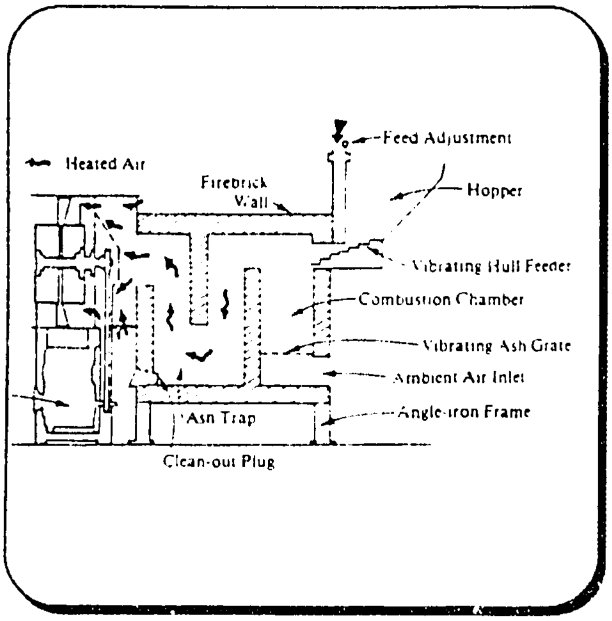


Figure 6.5. Schematic drawing of a biomass furnace.

- Forced ventilation system - In this system a fan pushes air through the mass of grain in a drying chamber. Some grain dryers have centrifugal (radial) fans while others use propeller type (axial) fans. Axial fans are less expensive than radial fans but are noisy to operate. They also produce less static pressure than centrifugal fans. However, they are more compact and lighter which make them easier to mount than centrifugal blowers. Figure 6.6 shows typical axial and centrifugal blowers used in grain dryers.

- Structural frame - It holds the grain and the other components of the dryer together. The general shape of dryers usually differentiates them from each other. Some dryers are vertical others are horizontal

- Prime mover - This drives the fan and other moving parts of the grain dryer. Some dryers have an electric motor to turn the fan while others have an internal combustion engine for this purpose.

- Control system - It regulates the temperature of the heated air. It is a means of starting and stopping the grain dryer if and when the drying air temperature is beyond a set limits. The control may also include a thermostat at the exhaust point. It turns off the heater automatically if the exhaust air humidity drops to minimum limit (about 60% RH for example).

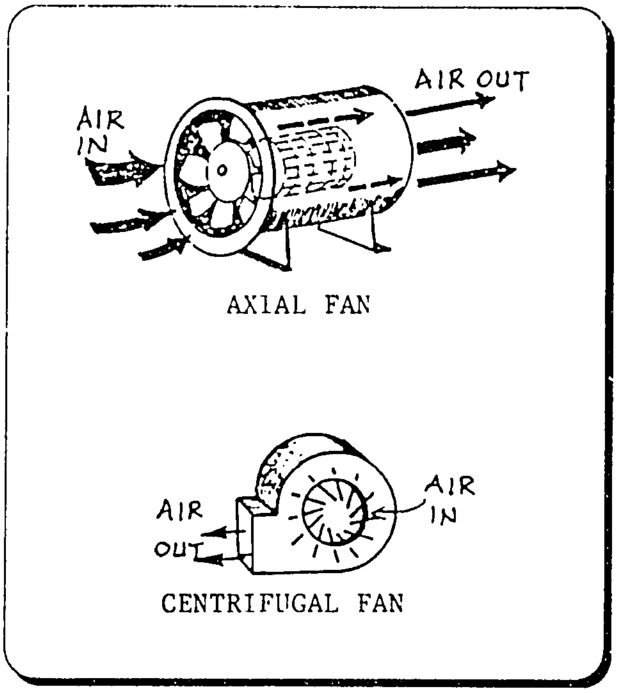


Figure 6.6. Typical axial and centrifugal fans used in grain drying and aeration.

4. Common Types of Grain Dryers - Grain dryers fall under a certain type based on what it does to the grain during the drying process. For example, some dryers will mix the grain while it moves through the drying chamber, hence, they are mixing type. Others allow the grain to move in a laminar manner. In some dryers, the grain does not move at all, thus they are non-mixing types. Many small portable farm type dryers have a system of constantly conveying back the grain to the dryer for further drying. Hence, they are re-circulating batch type grain dryers. However, most vertical dryers have a system of moving the partially

dried grain to tempering bins. This is to equilibrate the moisture in each grain before further drying it. These dryers are of the "continuous flow" type category. The "continuous flow" drying system is an efficient process and is the standard system in most of the processing plants in the grain industry. The various types of artificial grain dryers are as follows:

a. *Flat-bed batch type dryer* - It is the simplest artificial dryer used to dry grains and other agricultural products (Figure 6.7). It dries grain in a bed or box without stirring or moving the grain. It is an inexpensive dryer and simple to operate. It also requires a low level of technical skill to construct and operate it. Local shops can easily make the machine using simple tools out of locally available materials. However, it requires manual loading and unloading of the grain which is one of the drawbacks of this type of a dryer.

Another drawback of this type is the non-uniformity of grain moisture after drying. It also requires constant attention as the bottom layers of grain dry faster than the top layers. Hence, it is very easy to over-dry the bottom resulting in cracked grains or low germination of seed grains. Over-dried paddy rice will result in high percentage of broken grains.

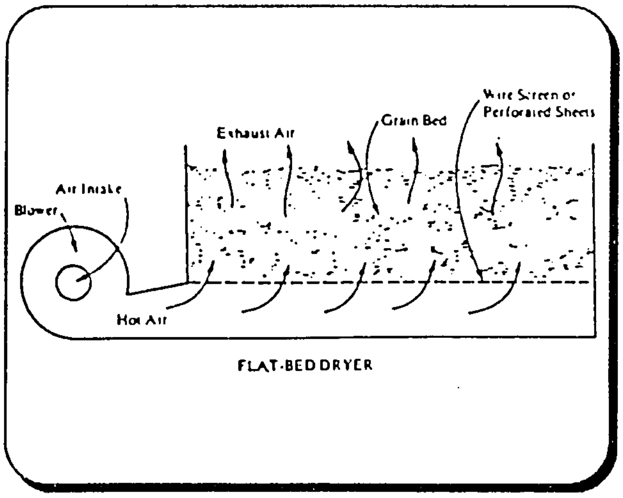


Figure 6.7. A typical flat-bed type grain dryer.

b. *Re-circulating - type batch dryer* - It is a dryer that dries a batch of grain by constantly circulating the grain until it is dry. This type of a batch dryer (Figure 6.8) produces more uniformly dried grains than the flat bed dryer. Because of its portability and simplicity it is a very popular grain dryer among grain farmers in the U. S. and other western countries.

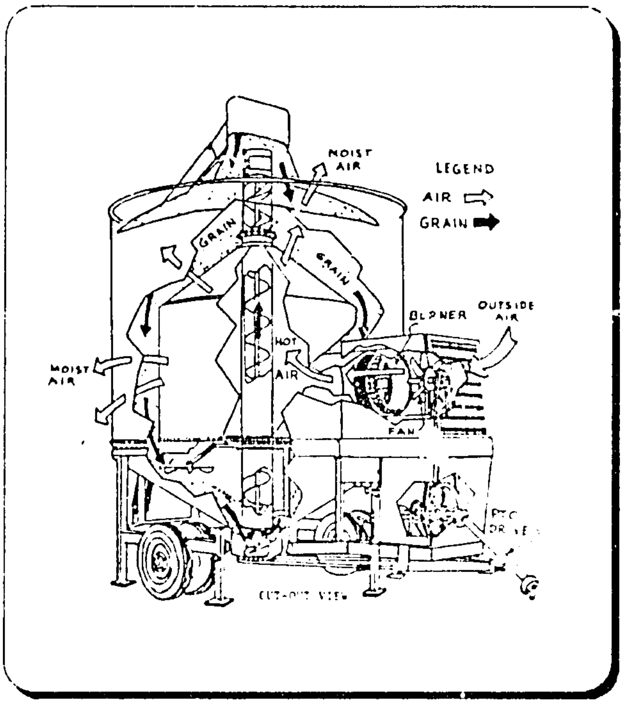


Figure 6.8. A typical recirculating-type batch dryer for farm drying operations.

c. *Continuous-flow dryer* - A grain dryer that is very popular in large grain drying operations. This machine dries grain more uniformly than batch dryers. It has narrow vertical drying columns about 15-20 cm thick. In some dryers, the columns have baffles that mix the grain as it moves down the column by gravity. The mixing action speeds up the drying process and produces a more uniformly dried grain. For this reason, plant managers prefer the continuous-flow dryer such as the LSU-type vertical dryer (Figure 6.9) over the batch dryers. Figure 6.10 shows the cross section of a typical continuous-flow grain dryers

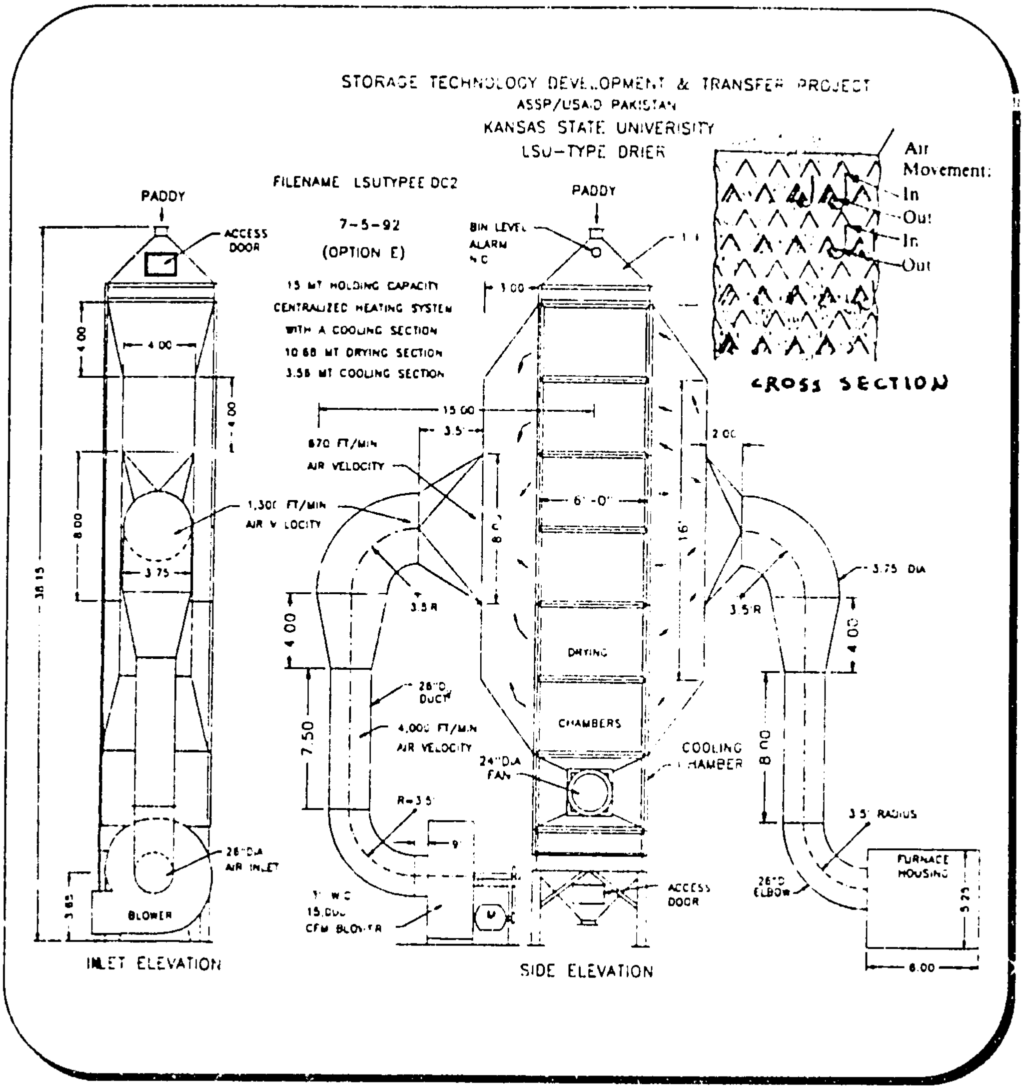


Figure 6.9. Schematic diagram of an LSU-type grain dryer the FFGI-KSU/USAID project developed in Pakistan.

6. Factors Affecting Drying Rates

The three most important factors influencing the drying rates of cereal grains are temperature, airflow rate, and grain thickness. The higher the temperature the faster is the drying rate. However, one should not exceed the maximum allowable drying temperature for various grains given in Table 6.1 below. Meanwhile, Table 6.2 gives the various airflow rates for different grains. The primary consideration in choosing air-flow rates are the power required and the efficient utilization of energy without sacrificing grain quality. The airflow rate is dependent on the kind of grain being dried and the design of the dryer. High air flow rates also speed up drying just like high temperatures but only to a certain extent. Air flow rates beyond this point is a waste of energy resulting in higher drying cost. A simple method of monitoring the performance of a grain drying operation is to determine the humidity of the exhaust air. If the exhaust air humidity is below 60% it is time to turn off the heater. At 60% relative humidity, the equilibrium moisture of most cereal grains is

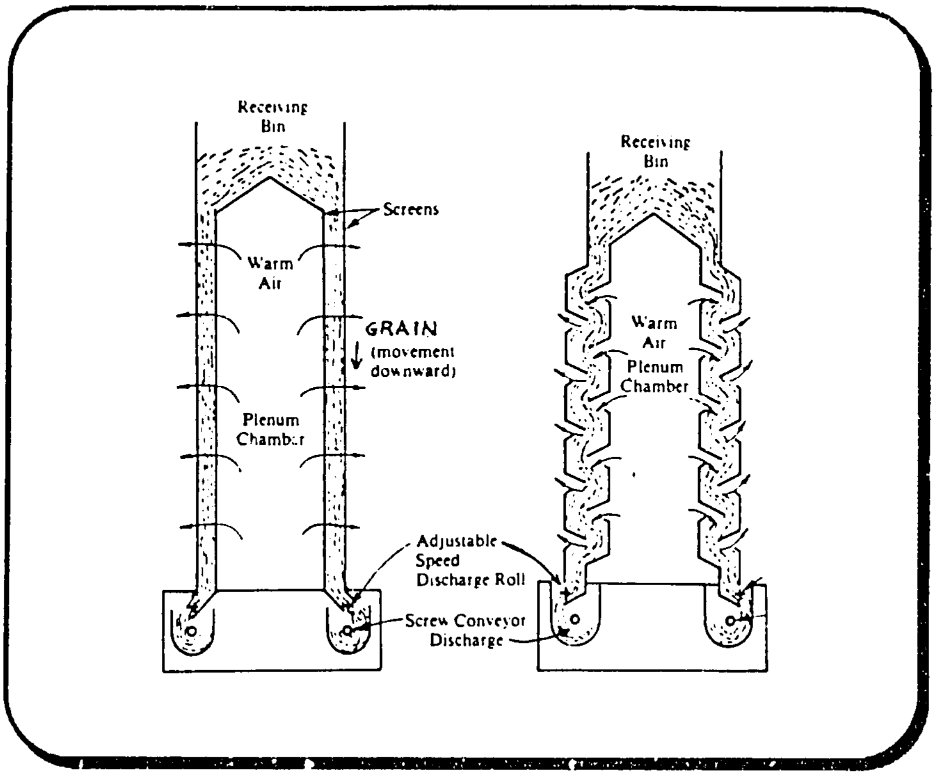


Figure 6.10. Cross-section of typical continuous-flow grain dryers.

Table 6.1. Drying temperatures for major cereal grains.

	Drying Temperature °C	Drying Temperature °F
For Food and other purposes:		
Corn	55-71	130 -160
Wheat	55-71	130 -160
Rice	40-43	104 -110
Sorghum	55-71	130 -160
Oats	55-71	130 -160
For Seeds:	43	110

Table 6.2. Typical airflow rates in grain drying.

	Cubic Meter Air/ Cubic meter grain	
Rice	25*	60**
Corn	25	60
Sorghum	30	65
Wheat	40	100

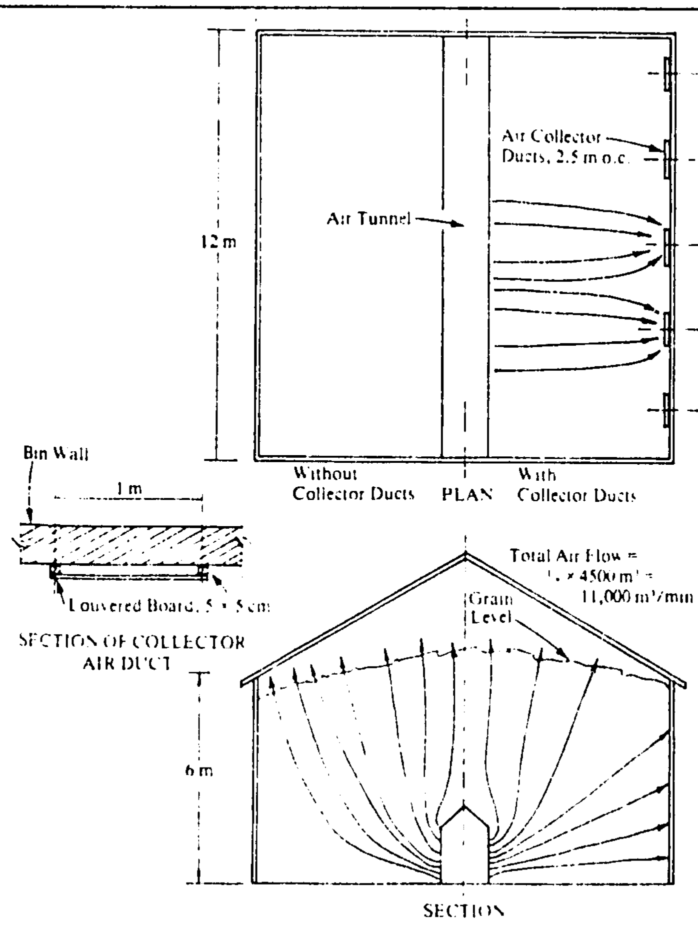
*Deep bed dryer
**Thin layer dryer

about 13%. During the initial stages of the drying process, the humidity of the exhaust air is high and then gradually decreases as drying progresses. As a rule of thumb the grain thickness in static or flat bed dryers should not exceed 45 to 60 cm maximum to avoid over-drying the layer of grain at the hot air entry point. For continuous-flow dryers the grain thickness is usually 30 cm or less for the same reason. Refer to the suggested references in for more in-depth discussions of cereal grain drying technology.

B. Grain Aeration

Grain aeration is a management process of removing excess heat from bulk grain with the main purpose of preventing hot spots and corresponding moisture migration. Moisture migration often leads to grain spoilage in the grain mass that increased in its moisture content. Chapter 4 discussed moisture migration phenomena as one of the factors contributing to storage losses in cereal grains. Aerating grain in storage takes a considerable period of time and uses much less airflow rates compared with grain drying process. For example, the typical airflow rates for aerating grains ranges from 1/10 to 1/40 CFM per 1.25 cubic feet of paddy while 35 to 70 CFM per 1.25 cubic feet of paddy for drying. The relatively low air flow rates in aeration systems allow us to push air through grains in extremely tall silos. Figure 6.11 is an illustration of a typical aeration system. Meanwhile, Figure 6.12 is a graphical method of determining moisture loss during drying and the formulas calculate initial and final weights of the grain.

Please consult the list of suggested references at the end of this Chapter for more in-depth discussion of this topic



Air distribution system with single air supply tunnel in a 4500 m³ bin with and without air collector ducts on sidewall

Figure 6.11. A typical aeration system for a grain storage silo

FORMULAS FOR CALCULATING
GRAIN MOISTURE

1. MOISTURE CONTENT, DRY BASIS:

$$\text{MC, \% d. b.} = \frac{\text{Weight of Moisture in Grain}}{\text{Weight of Bone Dry Grain}} \times 100$$

2. MOISTURE CONTENT, WET BASIS:

$$\text{MC, \% w.b.} = \frac{\text{Weight of Moisture in Grain}}{\text{Weight of moist Grain}} \times 100$$

FORMULA FOR CALCULATING WEIGHT
CHANGES IN GRAIN DRYING OPERATIONS

1. FINAL WEIGHT OF DRIED GRAIN:

$$\text{Final Weight} = \frac{(100 - \text{Initial Grain Moisture \%})}{(100 - \text{Final Grain Moisture \%})} \times \text{Initial Weight}$$

2. WEIGHT OF MOISTURE REMOVED:

Moisture Remove = Initial Weight - Final Weight

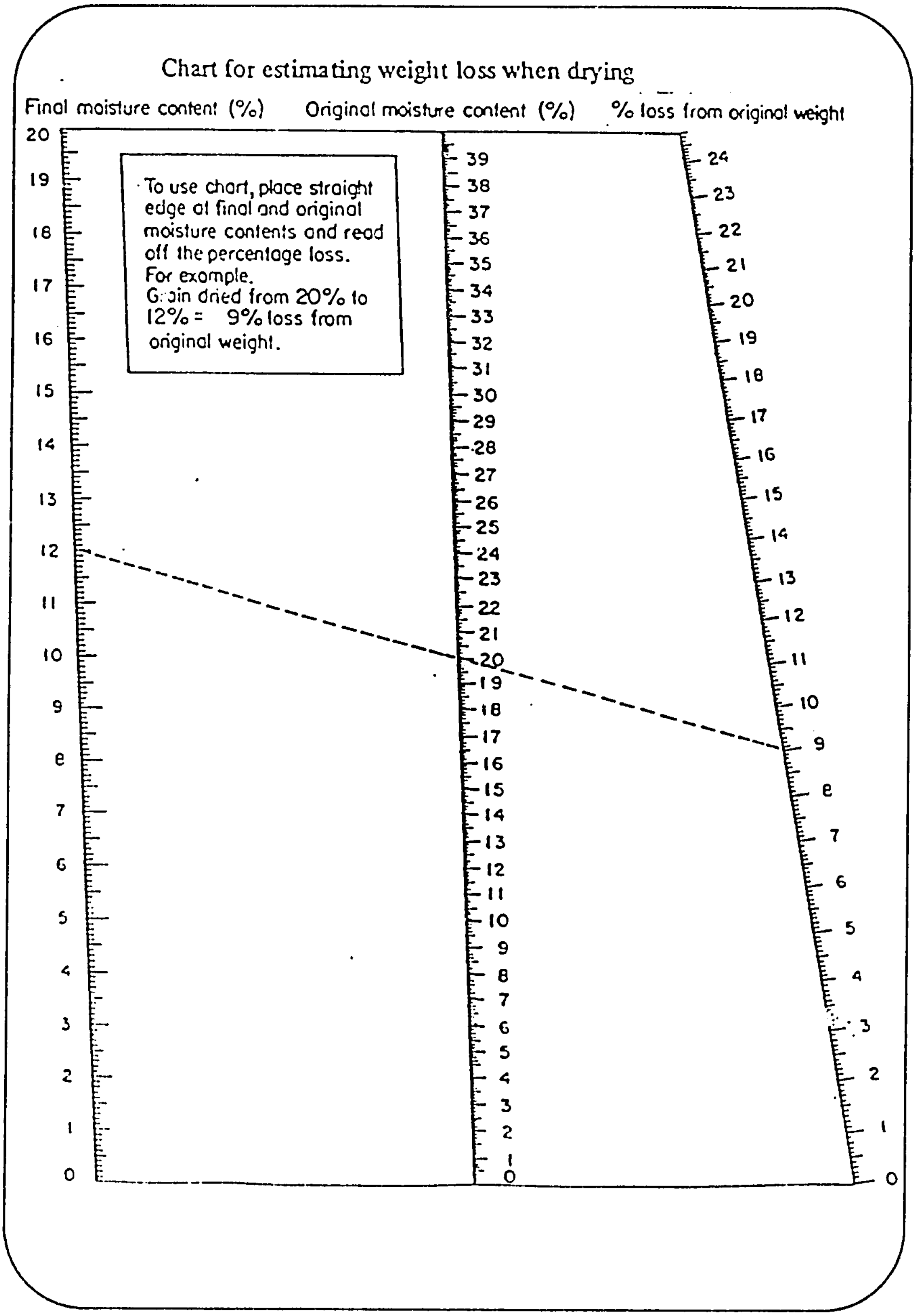


Figure 6.12. Chart for estimating changes in grain weight during drying or storage.

REVIEW QUESTIONS

1. What is the purpose of drying grains? How is it different from aeration?

2. Describe the two physical processes involved in removing moisture from the grain.

3. Give the two important factors affecting the rate of drying.

4. What is the form of the moisture we are trying to remove from the grain?

5. Give the main components of a mechanical dryer.

6. What is the ideal drying temperature for seeds and paddy?

7. Why is it important to give a rest period to the grain sometime during the drying process?

8. Explain the difference between moisture content dry basis and moisture wet basis.

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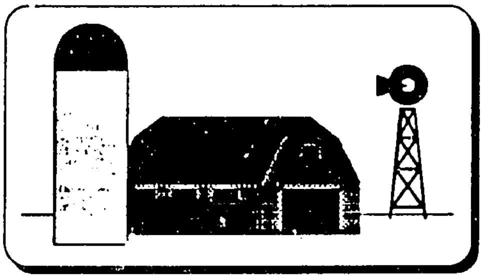

CHAPTER 7

GRAIN HANDLING EQUIPMENT

The introduction of machines during the Industrial Revolution changed the lives of peoples from the remotest islands in the Pacific to the great Continents of Asia, Africa, Americas, and Europe.

A. Introduction

Farmers produce grains in various systems of agriculture under a wide range of environmental and political situations. Environmental situations influence the entire postharvest system of handling and storing grains. The bag system of moving grains from the farm to the market is common in developing countries. Meanwhile, bulk handling of grains from producer to user is a standard practice in developed countries. This system of moving grains is very efficient and costs less per unit weight of grains handled. The use of specialized machines from transporting to processing provides a means of achieving efficiency.

Conveying implies the movement of material in any direction. It includes vertical, horizontal, and inclined movements of the product. The conveyors discussed below are either fixed or portable equipment depending on their use. There are various equipment available in the market that can convey grains under given conditions.

B. Types of Grain Conveyors

- Gravity conveyors
- Belt conveyors
- Chain or drag conveyors
- Screw or augers
- Bucket elevators
- Pneumatic conveyors
- Vibrators
- Throwers or slingers
- Hand carts and trolleys
- Electro-manetic system

1. Gravity Conveyors

a. *Characteristics*:

- Gravity conveyors are devices where the material flows without the aid of an external force other than gravity.

- Elevator pipes or spoutings and bag chutes are examples under this classification (Figure 7.1).

b. *Design considerations*:

- The coefficient of friction of the grain on a surface and its angle of repose are the two most important factors to consider in designing gravity conveyors. The sliding force should exceed the frictional force to make the product move down the conveying surface such as a chute.

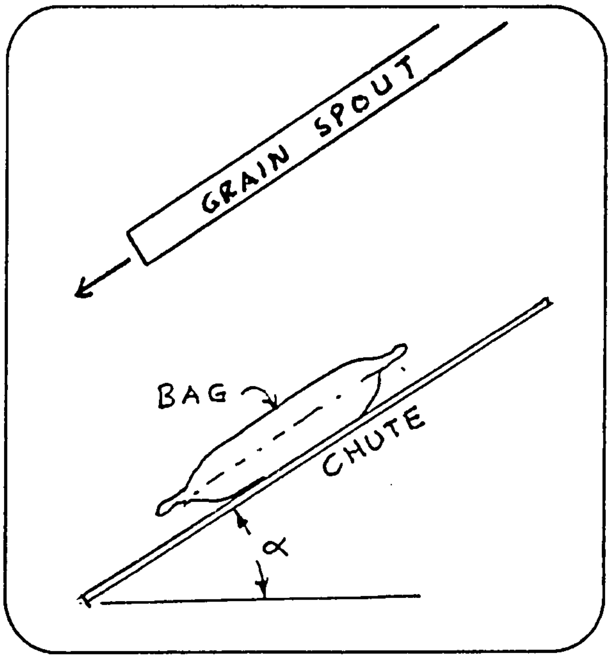

Figure 7.1. Schematic drawing of typical gravity spouts and chutes.

2. Belt Conveyors

a. *Characteristics:*

- The belt conveyor is essentially an endless belt which travel between two or more pulleys.

- It has the highest mechanical efficiency compared with other conveyors.

- Very gentle to the material it is conveying.

- Can convey materials at long distances either in bulk or in bags but has limited elevating capability.

- It has a complicated system of discharging materials between the main pulleys.

- If properly designed and maintained, it will have a long working life

- Its initial cost is high but its maintenance cost is usually low.

b. *Design considerations:*

- The drive must be at the discharge end of the conveyor and usually consists of V-Belt drives

- The pulley diameter is large enough to provide sufficient surface contact with the belt to insure a positive drive. The belt will also have longer working life

- Providing a snub pulley will increase the angle of wrap or surface contact between belt and pulley.

- It requires a take-up device to stretch the belt to offset the effects of loading and environmental factors.

- Idler pulleys or other devices are necessary to form the belt into a trough (see Figure 7.2).

c. *Horsepower required:*

- The total horsepower required is the sum of the HP_f for friction, HP_h for horizontal movement, and HP_e for lifting or elevating.

- It requires additional HP if it has a tripping device it

- The following formulas are useful in calculating the power required for a belt conveyor:

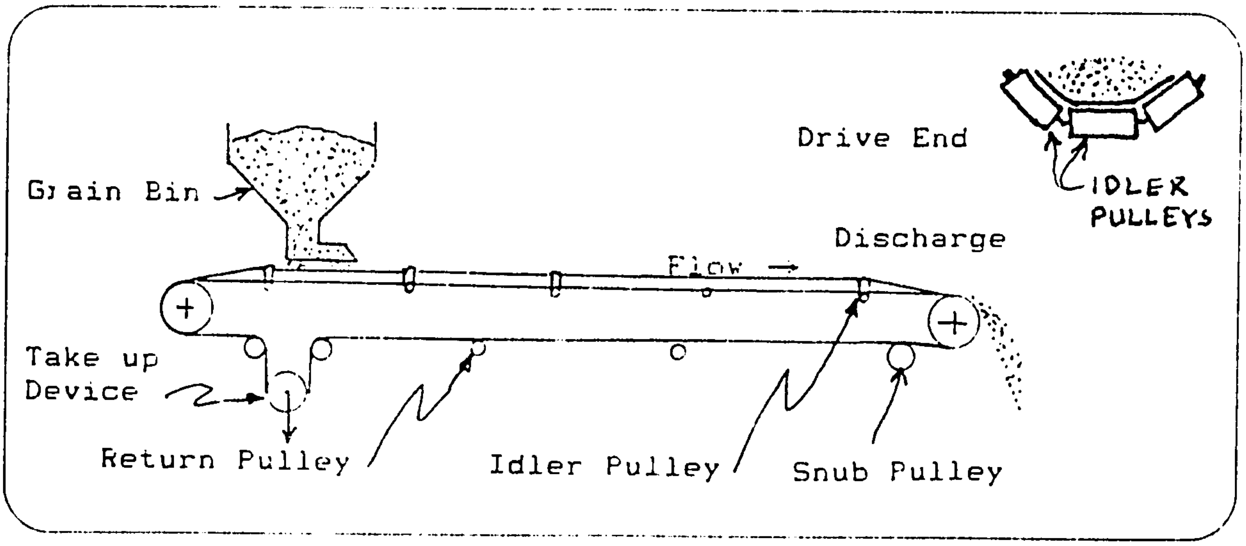

Figure 7.2. Schematic diagram of a typical belt conveyor design

- Tables 7.1, 7.2, and 7.3 are constants needed in calculating the horsepower requirement of a belt conveyor.

FORMULA FOR CALCULATING BELT CONVEYOR HP

Friction HP_f:

$$HP_f = \frac{\text{Belt Speed, M/min.}}{0.3048} \times \frac{A + B\,(3.281\,L)}{100}$$

Horizontal Movement HP_h :

$$HP_h = (TPH) \times \frac{0.48 + 0.01\,L}{100}$$

Elevating HP_e:

$$HP_e = \frac{\text{Lift}}{0.3048} \times 1.015 \times \frac{TPH}{1000}$$

Where: TPH = Capacity, Tons per hour
A,B = Constants (see Table 7.1)
L = Length of conveyor, meters

3. Chain or Drag Conveyors

a. *Characteristics:*

- Slow and noisy but are inexpensive and versatile.

- A specially designed conveyor can convey materials in a complete loop.

- Can easily discharge materials at different points if it has multiple discharge gates.

- A standard drag conveyor can convey materials even in very steep slopes.

- The conveyor trough cross section may have an "O", "U", or rectangular shape.

- It has minimum material carry-overs because of the close contact between scrapers and trough bottom.

- It is possible to start the conveyor under full load.

- Latest design in this category is known as "En masse" conveyor or "Grain Pump". They have higher capacity compared with an equivalent tube diameter screw conveyor. The grain pump loop can convey materials both horizontally and vertically.

- Figure 7.3 and 7.4 show typical drag conveyor designs.

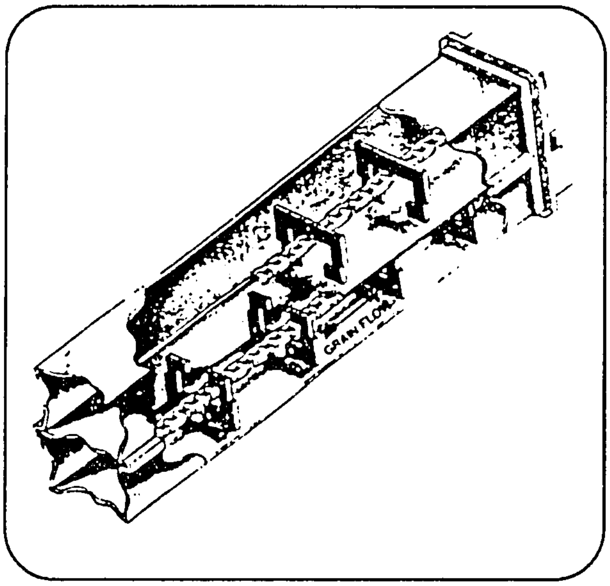

Figure 7.3. Details of the chain and paddle of a drag or chain conveyor.

b. *Design considerations:*

- Locate the drive at the discharge end.

- A chain drive usually transmits the power.

- Scraper or flight speeds range from 75 to 125 Ft/min. (23-38 meters/minute).

- It is preferable to increase scraper size than to increase its speed for higher capacity.

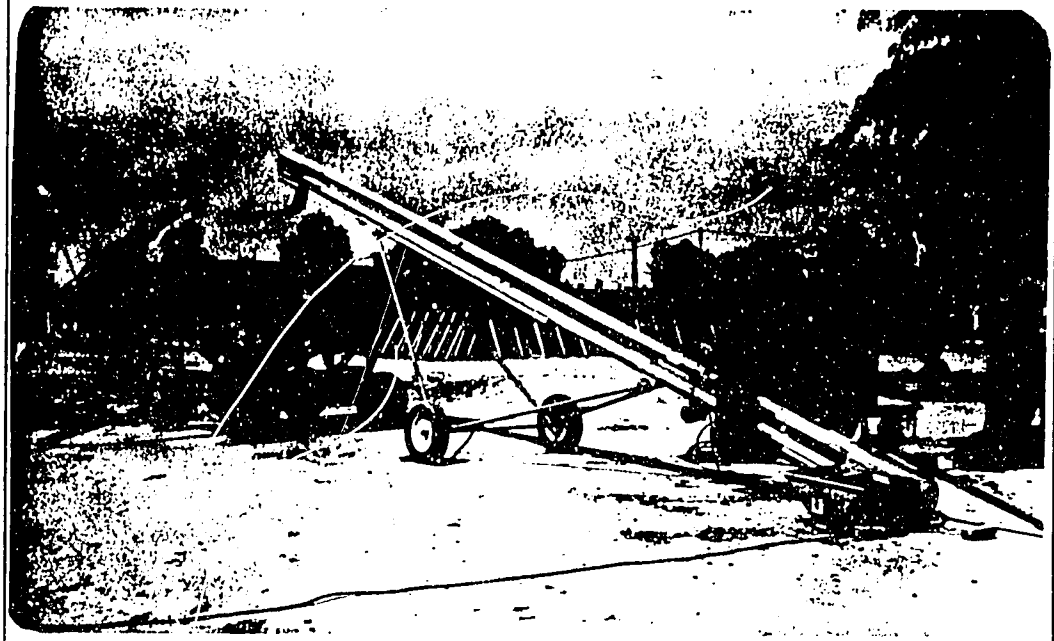

Figure 7.4. A portable chain conveyor used for grain handling operations.

- Conveyor capacity decreases with increasing inclination

- Scrapers or paddles are usually heat-treated or lined with abrasion resistant material for longer service life

-Ultra Heavy Molecular Weight (UHMW) plastic liners or abrasive resistant conveyor bottoms are available as options when ordering conveyor from manufacturers

c. *Horsepower required:*

- The power requirement of a drag conveyor takes into account the weight of the scrapers or flights and the coefficient of friction of the rubbing surfaces and material it is conveying

- The horsepower requirement for a drag or chain conveyor is calculated using the formula in the box

- Well established conveyor manufacturing companies usually have and can provide catalogs that are helpful in designing and selecting a grain conveying system.

FORMULA FOR CALCULATING DRAG CONVEYOR HP:

$$HP = \frac{2\,V\,L\,W\,Fc + C(L\,Fm + H)}{4558}$$

Where:

V = velocity of chain, meter/min
L = length of conveyor, meters
W = weight of chain and flights, kg/meter
Fc = friction of conveyor (see Table 7.4)
Fm = friction of material (see Table 7.4)
C = capacity, kg/min
H = height of lift, meter

4. Screw Conveyors

a. *Characteristics:*

- Can convey a wide variety of materials such as granules, powders, sticky or viscous products, and other substances.

- It performs some degree of material mixing.

- Its common use is in controlling the feeding rate of a given material.

- Changing the pitch of the flights either speeds up or slows down the material flow rate (see Figure 7.5).

- It can also convey most materials in a horizontal, inclined, and vertical directions.

- The conveying capacity decreases with the slope but much less than the drag conveyor.

- The flights are subject to severe wear depending on the product it is conveying.

b. *Design considerations:*

- Their casing can take the shape of a "U", square, or an "0." An auger has an 0-shaped casing.

- The conveyor bottom surface is usually case-hardened or lined with UHMW plastic sheet to resist wear when conveying very abrasive materials such as paddy rice.

- The length, inclination, type of flight, type of hangers, and characteristics of the material it is conveying greatly affects the power requirement.

- Provide extra power to overcome jammed screw and/or full start ups.

c. *Power requirement:*

- The formulas in the box are useful in calculating the horsepower requirement for a screw conveyor. The final power will depend on the equipment manufacturer.

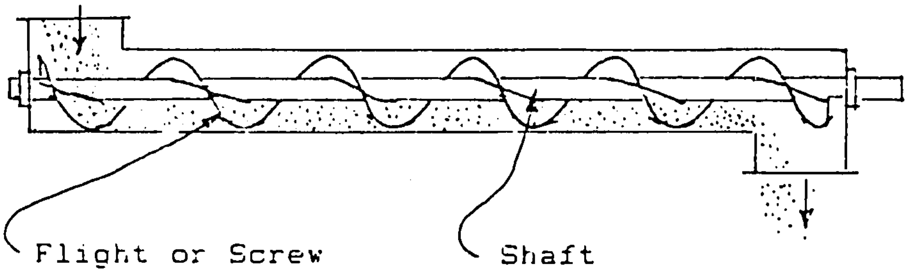

Figure 7.5. Components of a standard screw conveyor.

FORMULA FOR CALCULATING
SCREW CONVEYOR HP

$$H = L \times \frac{(DS + QK)}{1,000,000} = \text{Theoretical power}$$

where:

L = length in feet
D = factor on type of bearing (Table 7.5)
S = speed in rpm (Table 7.6)
Q = quantity of material, lbs/hr
K = material factor, 0.4 for cereal grains

Therefore, the required horsepower is:

$$HP = \frac{H \times P}{Eff}$$

Where:

P = 2 when H is less than 1
P = 1.5 when H is between 1 and 2
P = 1.25 when H is between 2 and 4
P = 1.1 when H is between 4 and 5
P = 1.0 when H is greater than 5
Eff = Estimated drive efficiency, 0.85

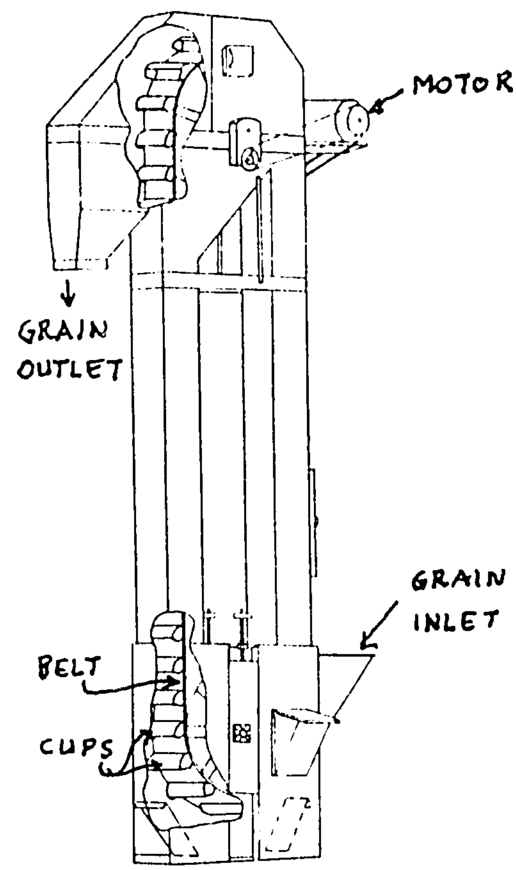

Figure 7.6. A typical bucket elevator.

5 Bucket Elevators

a *Characteristics:*

- It is an adaptation of the belt and chain conveyor

- It has plastic or metal cups bolted on the belt at specified distance

- They are very efficient conveyors because there is no friction between the material it is handling and conveyor

- They are relatively more expensive than chain conveyors.

- Heat bearings or pulleys and belt generate by friction can start a fire and possible explosion

b. *Design considerations:*

- A drop-bottom boot can minimize the problem of carry-overs.

- Just like the belt conveyor, the pulley diameter must provide sufficient surface contact to have an effective drive.

-The bucket has a critical velocity to discharge the material at the head pulley effectively.

-Table 7.7 gives the optimum rpm for a given pulley diameter.

- The bucket or cup shape and spacing determine the capacity of a bucket elevator.

- Its take-up device maintains proper tension of the belt to avoid slippage. Its best location is at the elevator boot.

c. *Power requirement:*

-The calculation of the actual power requirement of a bucket elevator is an involved process. However, one can estimate the HP required by using the simplified formulas and constants given in the following box.

FORMULA FOR CALCULATING BUCKET ELEVATOR HP:

$$HP = \frac{Q\,H\,F}{4562} = \text{Theoretical Horsepower}$$

Where:

Q = capacity, Kg/min.
H = lift, meters
F = 1.5 for down leg feeding of product
= 1.2 for up leg feeding of product
HP (Actual) = HP (Theoretical) plus 10-15%

6. Pneumatic Conveyors

a. *Characteristics:*

- Low initial investment but high operating cost.

- Very versatile conveyor. It can convey a wide variety of products at varying paths or directions.

- It has practically no carry-over problem. Widely used in the plastic, flour, and feed milling industry. It is very convenient device in unloading grains in shipholds.

- High power requirement and produces high noise levels.

- A dusty atmosphere is inherent at the discharge end.

b. *Design considerations:*

- Bends and elbows must have large radius to minimize pressure losses.

- Conveying air velocity ranges from 5,000-7,000 ft/min.(1500-2100 M/min.) for grains.

- The cyclone is usually an integral part of a pneumatic conveying system.

- Figure 7.7 and 7.8 show typical pneumatic conveyor arrangements.

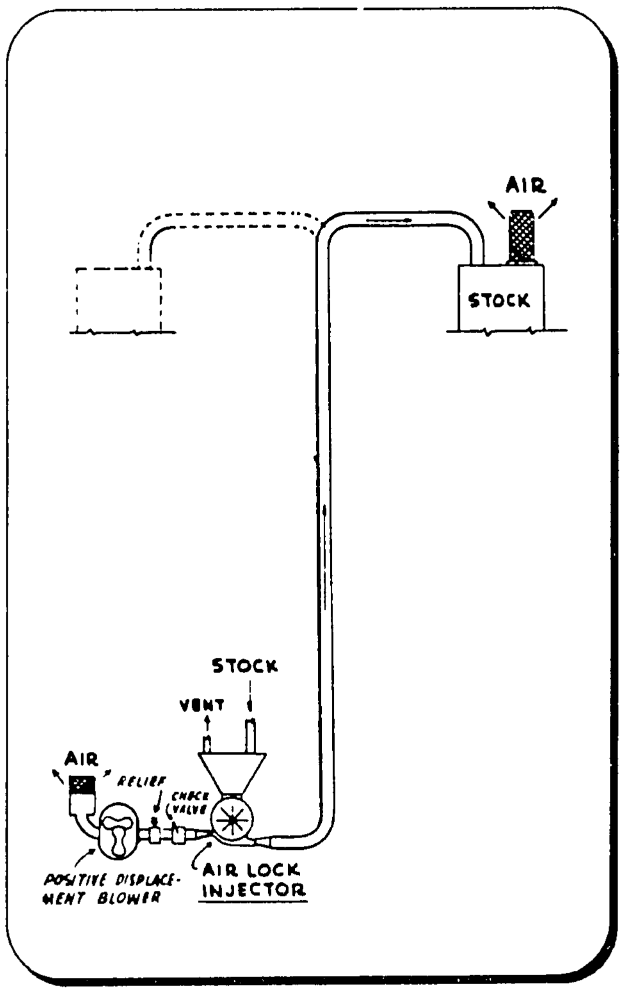

Figure 7.7. Schematic diagram of a typical positive pressure pneumatic conveyor.

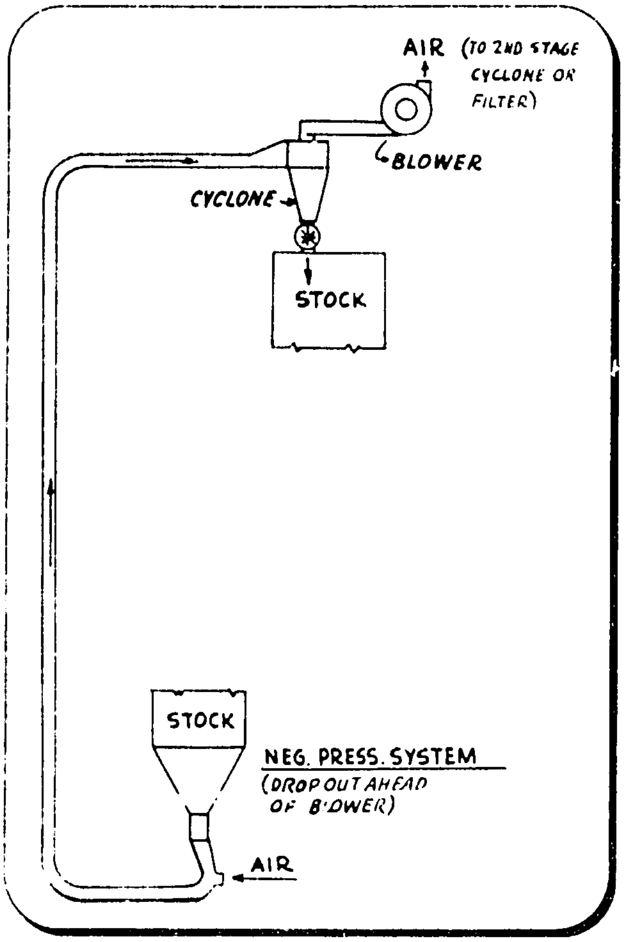

Figure 7.8. A negative pressure pneumatic conveying system

c. *Horsepower requirement:*

- The grain-to-air weight ratio determines the power requirement. It varies from 1:1.2 to 1:3.7

- The Gasterstadt equation below estimates the air pressure requirement of a pneumatic conveyor:

$$P = P_{air} (1 + 0.32 R)$$

Where. P = pressure drop for mixture, cm water
P_{air} = pressure drop for air only, cm water
R = weight ratio of grain to air (usually 2.5 for grains)

FORMULAS FOR CALCULATING HP OF A PNEUMATIC CONVEYOR:

$$kW = \frac{(Kg/sec)(Pa)(1.25)(0.12)}{102} + \frac{(Kg/sec)\ H}{6118}$$

$$= 0.00147\ W\ Pa + 0.000163\ W\ H$$

or

$$HP = kW / 0.745$$

Where:

Pa = pressure drop of air, Pascals
(1 cm water = 98.040 Pascals
= 98.04 Newtons/M^2)
W = combined weight of air and grain, Kg/sec
= Wa + Wg
Wa = weight of air, Kg/sec
Wg = weight of grain, Kg/sec
H = Vertical lift, meters

- The pressure drop for on a pneumatic system is usually 1.1-1.3 times that for handling air alone.

- Also, the horsepower requirement is 2 to 3 times the theoretical obtained by using 1.25 times the calculated pressure drop for air and the combined weights of air and grain.

Example: To convey 25 tons/hour of paddy rice to a height of 6 meters and 50 meters of horizontal distance will require about 67 motor horsepower. An equivalent bucket elevator will require no more that 5 horsepower motor or 20 horsepower for an inclined chain conveyor.

Table 7. 1. Constants A and B required in the formula for calculating belt conveyor hp.

BELT WIDTH (cm)	CONSTANS A	CONSTANS B	ADDITIONAL HP FOR TRIPPER
36	0.20	0.00140	0.70
41	0.25	0.00140	0.85
46	0.30	0.00162	1.00
50	0.30	0.00187	1.40
60	0.36	0.00224	1.70
76	0.48	0.00298	2.50

Table 7.2. Cross sectional area of loaded belt and maximum belt speeds.

CONVEYOR BELT WIDTH (cm)	CLEAR MARGIN (cm)	Total Cross Sectional Area (Cu.M)for 20 deg surcharge angle	Operational Speed (meter/minute) Normal	Maximum
30.5	4.1	0.0072	61	122
35.6	4.3	0.0089	61	122
40.6	4.6	0.0122	61	137
45.7	4.8	0.0161	76	137
50.8	5.1	0.0204	76	152
61.0	5.6	0.0308	91	183
76.2	6.4	0.0504	107	213

Table 7.3. Conveyor belt speed, pulley diameter, and corresponding shaft speed.

BELT SPEED		Pulley shaft RPM when pulley diameter is:				
(meter/min)		50 cm	60 cm	76 cm	90 cm	110 cm
30		20	16	14	11	9
46		28	24	20	16	14
61		38	32	25	22	18
76		48	41	32	27	24
91		55	48	38	32	27
107		65	55	45	38	32
122		75	65	51	43	36

Table 7.4. Friction coefficients of various conveyor surfaces and grain.

MATERIAL	FRICTION COEFFICIENT
Metal on wood	0.50 - 0.60
Wood on wood, parallel fiber	0.48
Wood on wood, cross fiber	0.32
Cast iron on mild steel	0.23
Mild steel on mild steel	0.57
Grain on rough wood	0.30 - 0.45
Grain on smooth wood	0.30 - 0.35
Grain on iron	0.35 - 0.40
Malleable roller chain on steel	0.35
Roller bushed chain on steel	0.20

Table 7.5. Factor D for various hanger bearings used in calculating screw hp.

Conveyor Diameter (cm)	Ball or Roller	Wood,Babbit Bronze or Molded fabric	Self Lubricating Bronze	White iron Manganese Steel
7.5	10	15	24	35
10	12	21	33	50
15	18	33	54	80
23	32	54	96	130
25	38	66	114	160
30	55	96	171	250
35	78	135	255	350
40	106	186	336	480

Table 7. 6. Capacity of screw conveyor at recommended speeds.

Screw Diameter (cm)		Maximum Recommended Speed RPM	Capacity (cubic meter/hour) At Maximum Recommended Speed	Capacity (cubic meter/hour) At 1 RPM
10		130	1.61	0.012
15		120	5.10	0.043
23		100	15.86	0.159
25		95	22.09	0.232
30		90	33.98	0.378
35		85	50.69	0.596
40		80	71.07	0.888

Table 7.7. Recommended rpm for a given diameter of a bucket elevator pulley.

PULLEY DIAMETER (cm)	HEAD PULLEY SPEED (Rev per min)	RECOMMENDED BELT SPEED (Meter/Min)
30	56	53
41	51	65
51	46	73
61	42	80
76	37	89
91	34	98
122	31	119

REVIEW QUESTIONS

1. What makes a belt conveyor more efficient than the other types of conveyor?

2. Which conveyor is the most common in your locality? Why is it so?

3. What factor affects the capacity of a bucket elevator?

4. What makes a pneumatic conveyor popular in the feed and flour milling industries?

5. What is the main drawback of pneumatic conveying system?

6. What type of conveyor is the "grain pump"?

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CHAPTER 8

GRAIN STORAGE

The storage of grain is an activity that man devised to ensure the availability of food from one crop season to the next. To ensure grain stability we must keep the grain in a suitable storage place.

The removal of non-grain materials before storage improves the keeping quality of grains. The ancient Egyptians and other civilizations used this procedure ever since they started cultivating and producing grains. For grain storage, they used containers in various shapes, sizes, materials of construction and features to protect the grain from damage. They even buried their surplus grains to hide it from their enemies. Perhaps that's where the idea of strategic food reserve originated from.

A. Basic Requirements For A Grain Storage System

Regardless of the reason for storing grains, the system must satisfy the following basic requirements:

- **Structure** to keep the grain from the weather, damage by pests, and contamination from the environment

- **Secure** from pilferage and physical losses caused by man and animals.

- **Convenient** for grain and facilities inspection, inventory control, grain conditioning, and pest control purposes.

- **Accessible** for handling, receiving, and dispatching purposes.

- **Appropriate** for the level of skills available

- **Durable and economical** to minimize storage cost

B. Classifications of Storage Facilities

All storage facilities can fall under two classifications, namely, (a) based on dimensional proportions, and (b) based on usage. The classifications apply regardless of size, materials of construction and shape. Based on the first classification, a storage structure can either be flat (horizontal) or upright (vertical) storage facilities. Figure 8.1 describes the proportions of a flat storage system while Figure 8.2 is a typical upright or vertical storage structure configuration. This grouping is very important to a design engineer because of the fluid behavior of bulk grains. Meanwhile, on the basis of usage a storage facility is either a temporary facility or a permanent one.

C. Types of Storage Based on Dimensional Proportion

1. *Flat Storage Systems*

Characteristics:

- The height is less than the diameter or width of the structure (Figure 8.1).

- It is the most popular storage facility in developing countries because of its versatility.

- Simple construction with or without aeration system

- Most have elevated floor at the same level with standard truck bed for ease of loading and unloading products

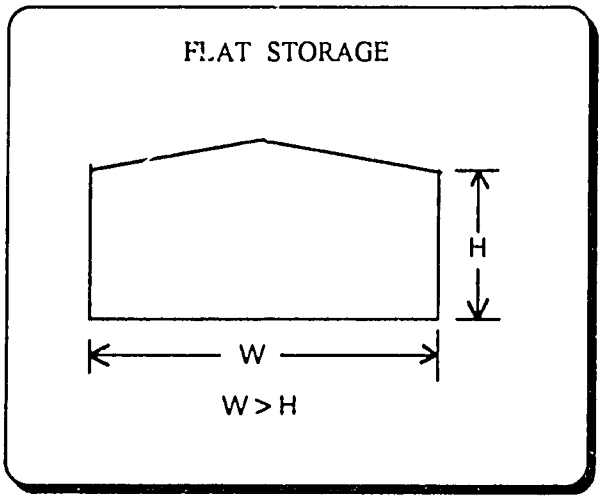


Figure 8.1. A flat storage structure like a warehouse

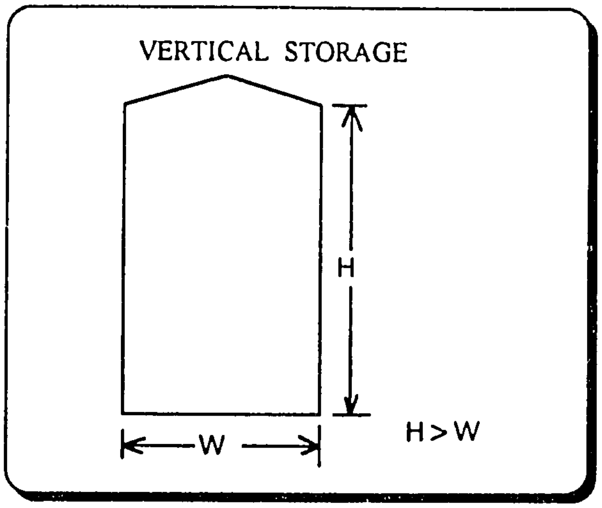


Figure 8.2. An upright grain storage structure like a grain silo.

- Visual inventory control is a standard practice.

- One can use it either for bag or bulk storage

- It is possible to use mechanized grain handling system.

2. *Upright or vertical structures*

Characteristics:

- The height is greater than the width or diameter of the structure (Figure 8.2).

- Tall metal or concrete silos are examples of vertical storage structures.

- They require mechanized grain handling system

- An aeration system is necessary to prevent moisture migration and grain spoilage.

- Cleaning and dust collection systems are optional features

- Fumigation is possible if the structure is gas or airtight

- Usually built individually or in clusters

- Individual structure capacity ranges from a small working bin of 20 MT to a large 4,000 tons silo in a grain terminal.

D. Temporary Storage Facilities

1. Outdoor Bag Storage. - This is a very common method of storing grain temporarily in many developing countries specially during the harvest season. Grain merchants or even the food agencies pile the bags in rectangular or pyramidal forms. The storage time usually depends on their ability to transport the grain to a more permanent facilities. Figure 8.3 is a typical outdoor bag storage in Pakistan.

2. Outdoor Bulk Storage. - This is a common temporary storage system in grain surplus areas where there is inadequate permanent storage facilities. Producers and buyers simply dump the grain on the ground while awaiting transport to a more permanent storage facilities. Bulk grain in the open either have plastic or tarpaulin covers or nothing at all. The need for covering depends on the climatic factors in the locality. If there are frequent rains, an outdoor bulk storage requires a good protection to avoid unnecessary grain losses.

Some facilities have plastic canopies or domes that require air pressure as support for their structure. Other facilities simply let the plastic cover rest on the surface of the grain. Regardless of the type of covering they use, all require mechanized grain handling system. The open bulkhead storage facilities in Pakistan originated from Australia. One of the advantages of this type of storage facility is its relatively low initial cost as compared with other storage structures. Other advantages are their simple construction and ease of installing them. With proper tucking and sealing of the plastic cover, it is possible to control insect infestation by fumigating the entire bulkhead. Covered bulk grain storage are popular in countries where they have surplus of grains and do not have sufficient permanent structure for storage. The schematic diagrams in Figure 8.4 and Figure 8.5 are less expensive system of outdoor storage compared with the covered storage shown in Figure 8.6.

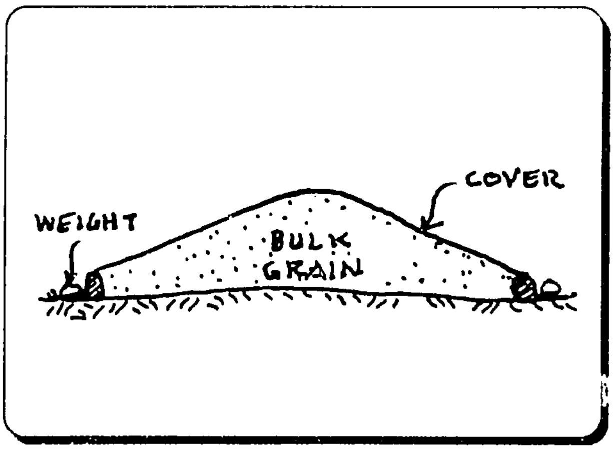


Figure 8.4. Diagram of a covered bulk storage that is simple and inexpensive to build.

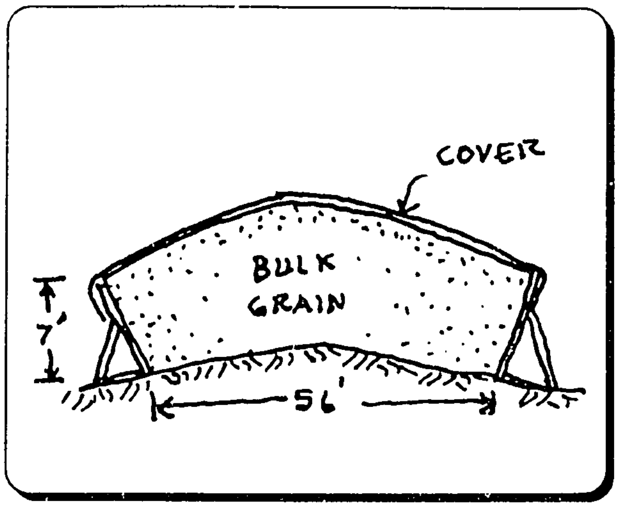


Figure 8.5. Schematic drawing of a covered bulk storage facilities used in Pakistan.

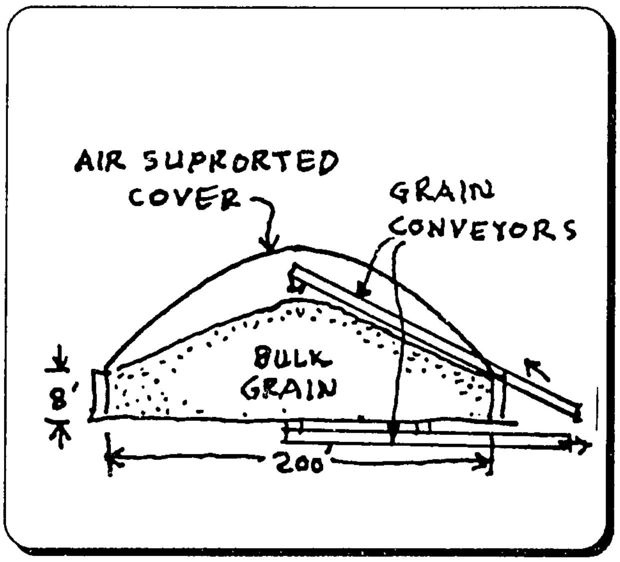


Figure 8.6. Schematic drawing of a covered bulk storage facility used in the U.S.

E. Permanent Storage Facilities

1. Bag Warehouse - The bag warehouse or godown is the most popular type of grain storage in most developing countries (Figure 8.7). It is simple to construct which only requires locally available construction materials to build. Its versatility is the single most important feature of this type of grain storage facility. It can store a wide range of commodities from food to non- food products. A properly designed godown should be able to store grain either in bag or bulk form. A godown dedicated for bulk storage can use standard grain conveying equipment system.

The principal drawback of a godown dedicated for grain storage is the difficulty in controlling insect infestation and doing any grain conditioning operations. Monitoring the quality of the grain stored in it is superficial at best. In countries where labor is abundant and relatively cheap, a bag warehouse is very economical to operate.

However, the versatility of a warehouse oftentimes become its weakness. It is very common to see poorly managed grain warehouses where grains get mixed with other commodities. Sometimes warehouse are so stacked that it is impossible to practice First-In First-Out (FIFO) stock management principle.

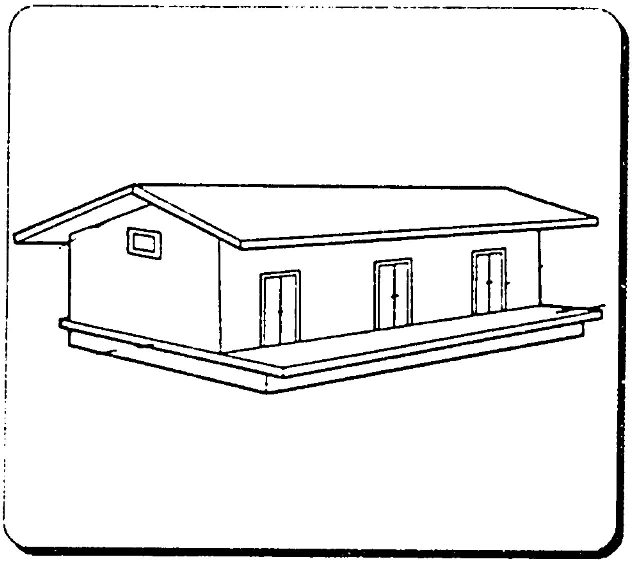


Figure 8.7. A typical warehouse for grains

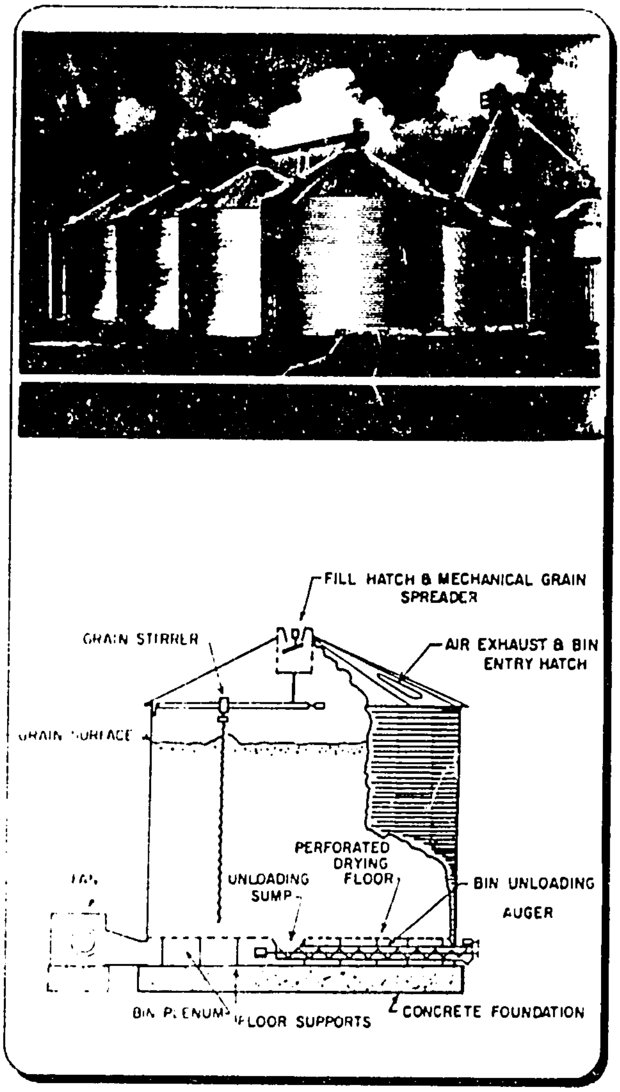


Figure 8.8. Farms silos for grain storage

2. Farm-Type Storage Silos

Storage capacities for each silo ranges from 25 to 80 MT each. It is an inexpensive storage system and easy to erect. The cluster of metal silos shown in Figure 8.8 is a common sight in many farms in developed countries. It is possible to use artificial grain drying system with these silos as well as conditioning the grain by aeration technique. Insect control is easy to perform if the silos are gas tight. An equivalent grain storage made of concrete is the typical hexagonal bin clusters found in Pakistan. The British constructed dozens of this type in Pakistan before independence for food reserves purposes. Each bin has a capacity of about 35 to 40 MT. However, for all these years workers have to climb 52 steps to the top of the bin cluster to pour grain manually. During the early years the weight of each bag of wheat was only about 40 Kgs.. Today each bag of wheat weighs 100 Kg. It was only recently that the Food Department has filled some hexagonal bin complexes mechanical with technical assistance through a USAID Project in Pakistan. Figure 8.9 shows a portable grain conveying system filling a hexagonal bin cluster in Punjab. The small metal silos shown in Figure 8.10 were actually edible oil tanks made locally. The tanks became grain silos by simply installing portable aeration and grain handling systems, respectively.

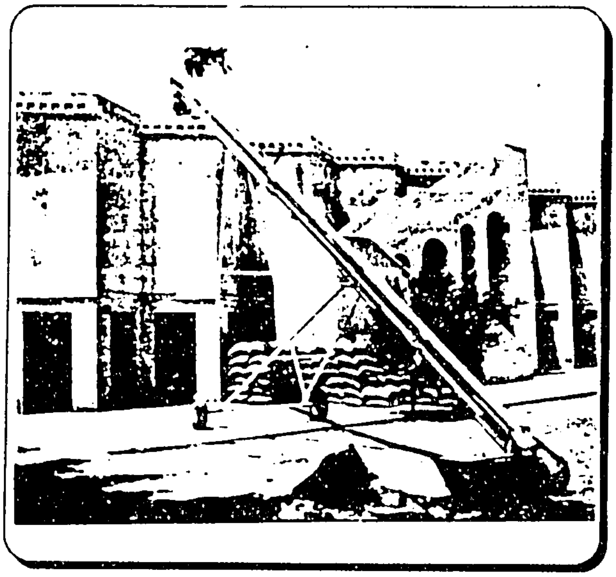


Figure 8.9. A hexagonal bin complex with a portable chain conveyor for filling bulk wheat.

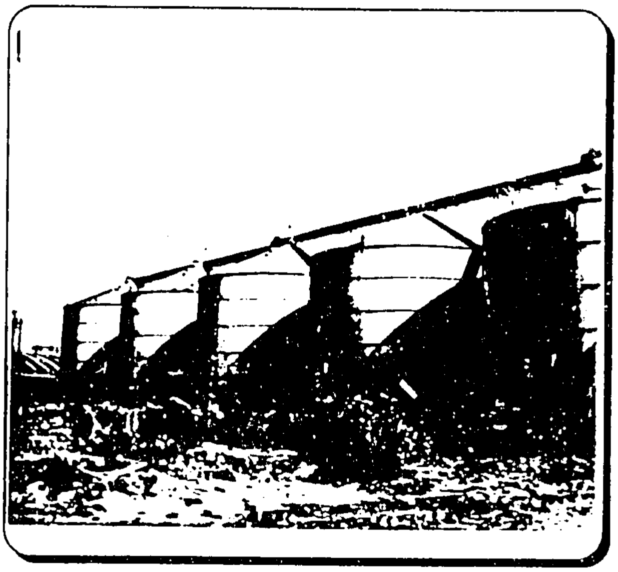


Figure 8.11. Metal silos of the Punjab Food Department in Pakistan.

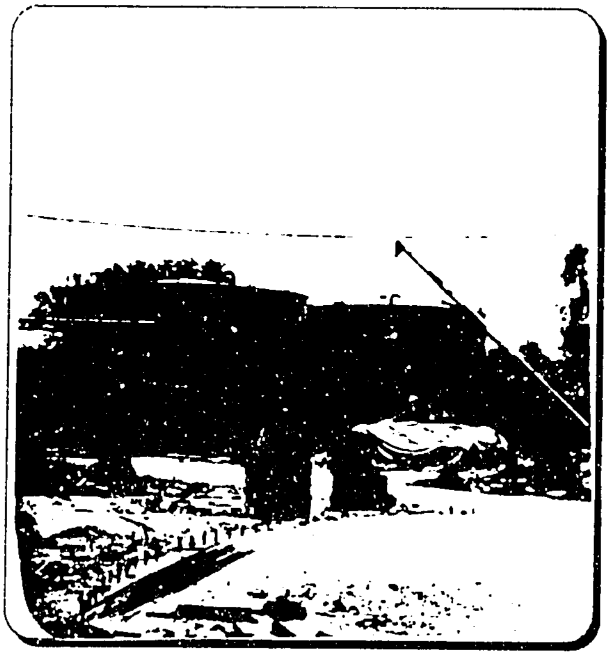


Figure 8.10. A locally made oil tank converted into grain storage for a local feed mill.

3. Commercial Storage Silos - Concrete silos are standard structures in larger grain storage facilities. They are much taller than metal silos and have smaller diameter silos in clusters with greater total storage capacity. This type of storage complex requires very high capital outlay, low maintenance cost, and last for many years. Metal silos are normally add-on storage facilities with the purpose of increasing the storage capacity of a storage installation.

a. *Country elevators*. As the name suggest, they are basically storage facilities dedicated for the storage of e grain in a given locality for either short or long-term storage purposes. The metal silos in Figure 8.11 fall under this category. The Government of Pakistan built the facilities for the storage of buffer wheat stocks. The features of this storage facility include the following:

- Producers can deliver directly to these elevators
- Cooperative societies or food agencs usually own such storage facility
- It may be a part of a regional storage network
- Capacity of individual silos ranges from 500 to 3,000 MT
- A minimum of four silos in each elevator is very arrangement common.

b. *Grain terminal elevators*. -The word terminal elevators imply that it is at the end of the line. This is basically true as this is the last stop before the grain goes to the end users or consumers. The end users may be feed mills, flour mills, or other processing plants. Grain terminals have the following features:

- Total storage capacities range from 300,000 to 500,000 MT.
- It usually belongs to a the government or to a large private food company.
- Artificial grain drying and aeration are standard fixtures.
- Possible to apply insect protectants during loading or at a later time.
- Grain conditioning and blending facilities are standard features.
- Strict pest control measures are in place.
- A rail system is almost always a part of it.

The concrete silos in Figure 8.12 are the latest addition to the series of bulk storage complexes in Pakistan. With properly trained personnel, the Government should be able to use it to store buffers stock of wheat.

c. *Export/import elevators.* - These are facilities that can move grain to and from ships at very rapid rates to avoid demurrage costs. Most modern port facilities all over the world have grain elevators for grain import and export purposes.

The main features of an export elevator include the following:

- They are similar to a terminal elevator in size and shape but are normally located inside export zones.

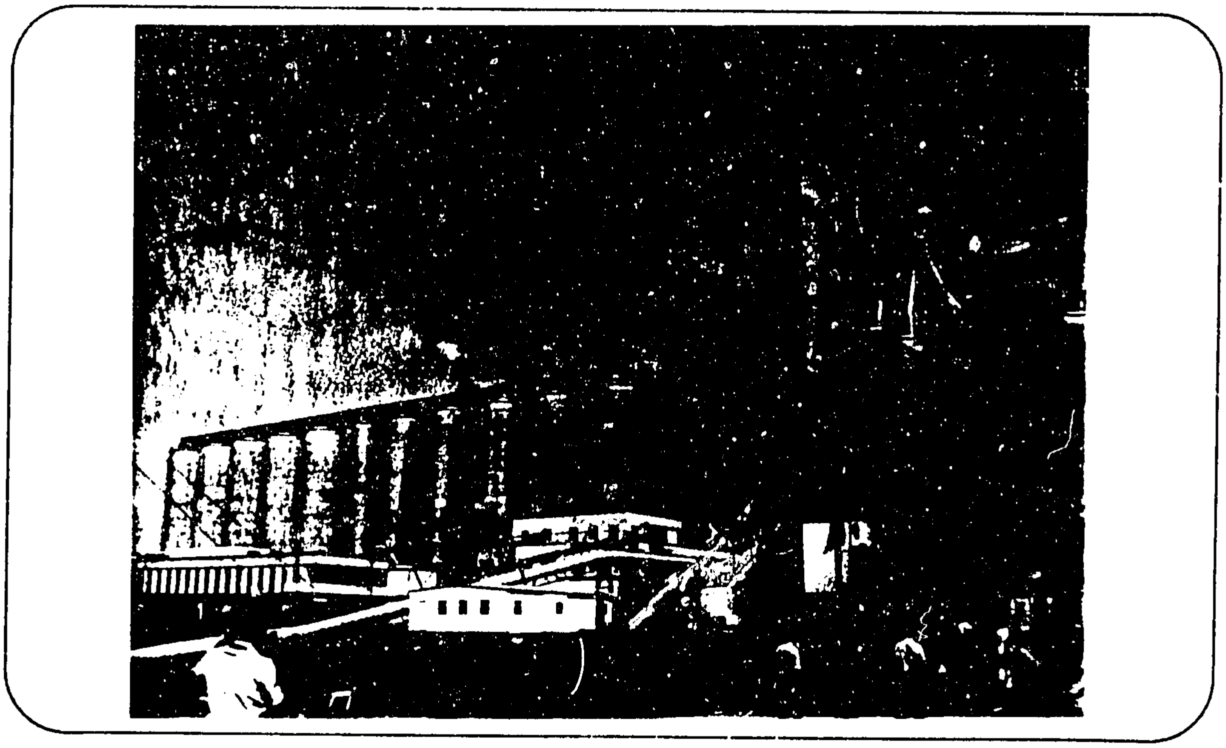


Figure 8.12. Picture of an export terminal elevator in Houston, Texas.

- They have very specialized grain handling systems to load and unload grains on ships and barges.

- They have strict control of grain quality to meet international grades and standards.

- There are always licensed grain inspector and graders stationed at these elevators.
-

F. Non-Conventional Storage Facilities

They are storage facilities that do not fall under the previous groupings of grain storage structures. The following are unique types with potential application in many developing countries.

1. Underground Grain Storage - This type of storage is most popular in arid areas in the African continent although a commercial size exists in Argentina.

- Primitive societies perhaps used this as their principal method of grain storage.

- Some African countries like Morocco still use this type of grain storage.

- It is simple to construct but difficult to retrieve stored grain.

- Temperature fluctuation is minimal.

- Control of insect by oxygen depletion is feasible.

- Concealment is a major feature.

- Water infiltration is a major problem.

2. Convertible Godown - This is a specially designed warehouse which can store either grains in bags or grain in bulk form. The walls must have the strength to sustain the horizontal pressure exerted by the loose grain stored in bulk form. This type of storage structure requires mechanical means of loading and retrieving bulk grain. It can have either a fixed or portable grain handling system. However, a godown that handles grain on a continuous basis is usually more efficient and economical to operate than one with portable system. This situation normally exists in a processing plant or in a food agency distribution center. However, a portable system of loading and retrieving may be more cost effective in a storage complex for long term storage of grain reserves. In this case, one set of conveying equipment can serve several godowns thus reducing the unit cost of handling grains. Both **fixed** and **portable** loading systems are now in use in Pakistan by the Pakistan Agricultural Storage and Services Corporation (PASSCO). The schematic diagram in Figure 8.13 show the fixed system of grain handling of a convertible godown. There are two flour millers in Pakistan that now have this type of a godown. Meanwhile, the diagram in Figure 8.14 and picture in Figure 8.15 show the portable grain handling system of a convertible godown.

3. The Cyprus Bins - This storage technology originated in Cyprus and found its way in Kenya some 15 years ago. It is basically a sealed concrete structure whose upper structure is dome shaped. Its lower half is a mirror image of the upper portion and lies below ground level (Figure 8.16). It uses portable grain handling equipment for filling and retrieving operations. The structure is very convenient to fumigate since it has sealed hatches which neither has doors nor windows. However, the site must have good drainage system and the entire structure made watertight. Water seepage and leakage means instant spoilage as they do not have aeration system. Surprisingly, the Kenyans successfully stored yellow maize for four years with little or negligible grain quality loss.

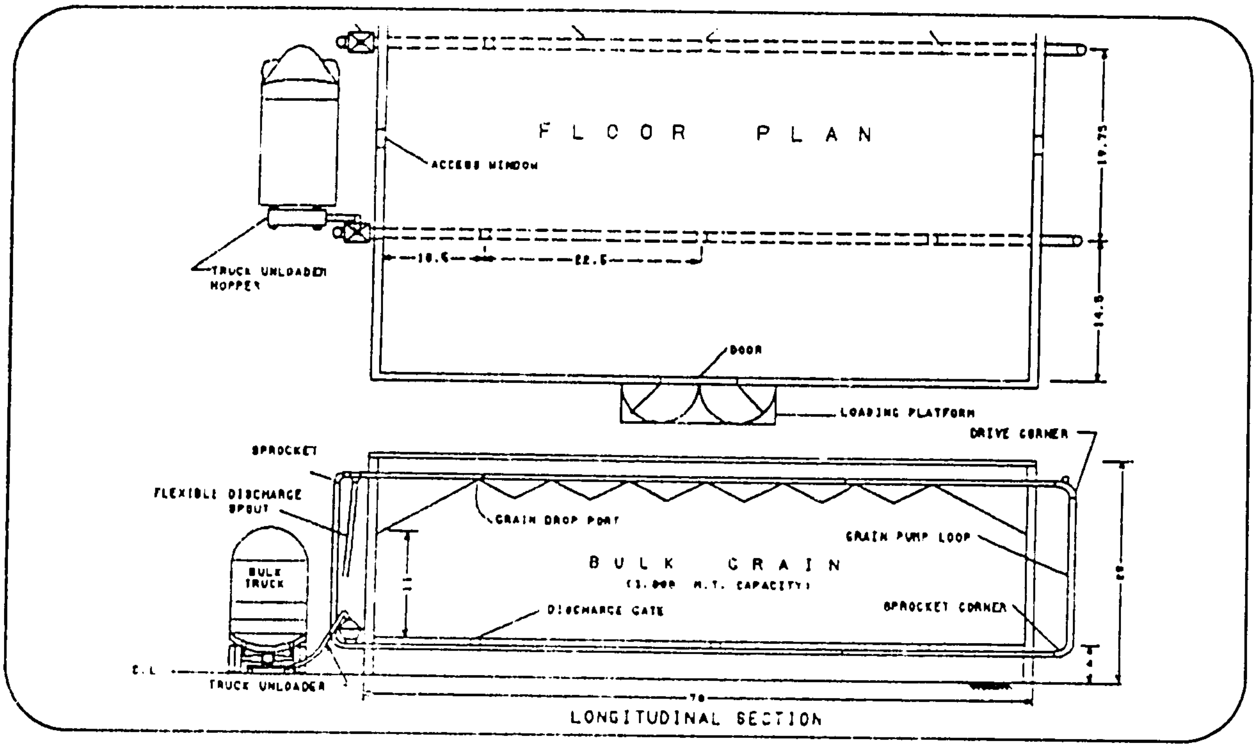


Figure 8.13. Schematic diagram of a convertible warehouse with fixed grain handling system.

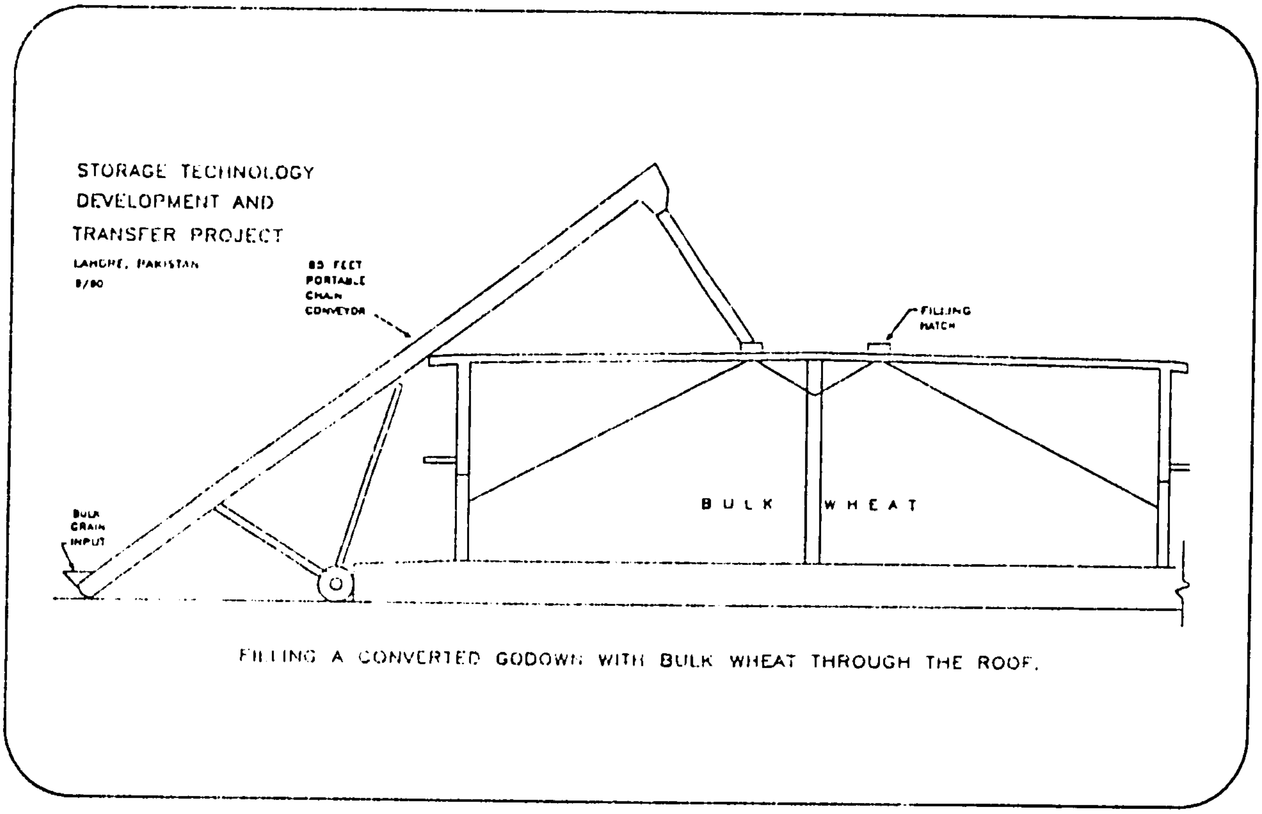


Figure 8.14 Schematic diagram of a convertible warehouse with portable grain handling system.

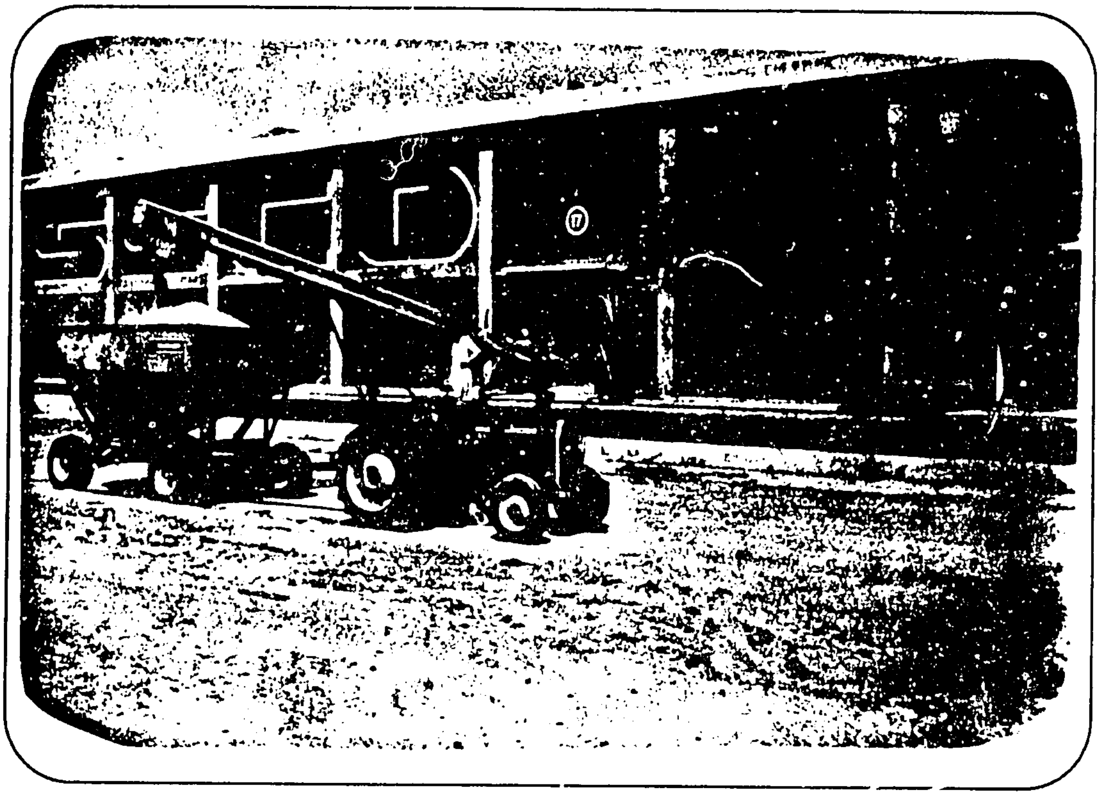


Figure 8.15. Picture of a bulk grain retrieving operation in a convertible godown.

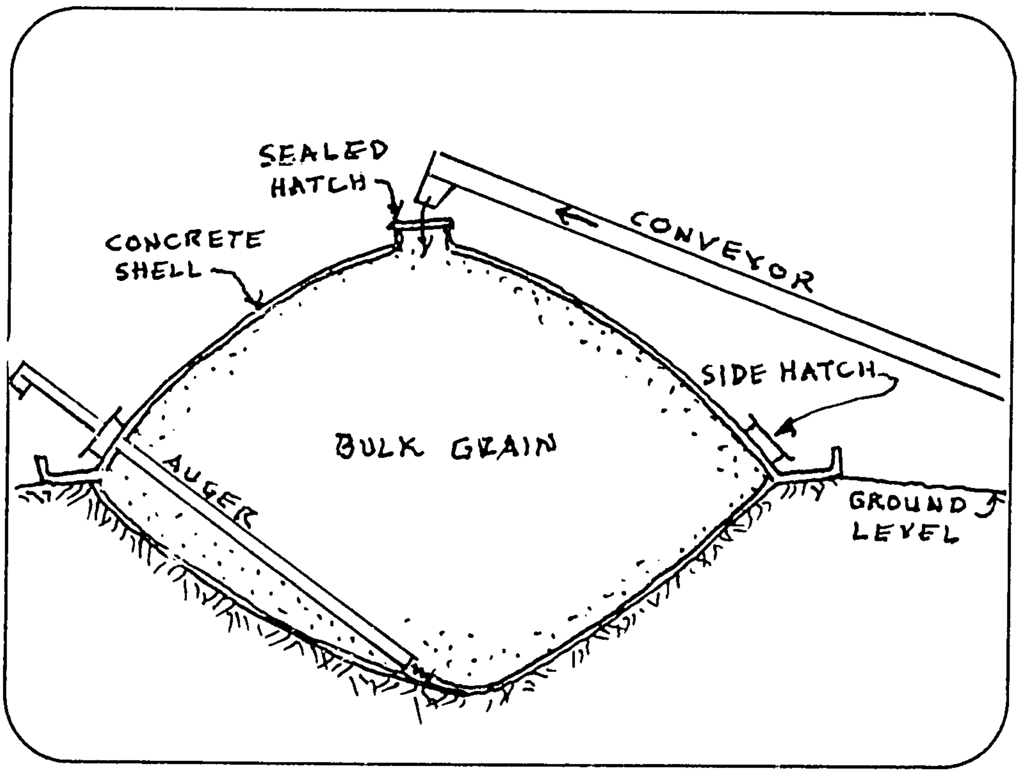


Figure 8.16. Schematic diagram of a Cyprus bin.

G. Considerations in Selecting Type of Storage

1. Economic Factors

- Cost of structure and availability of financing.
- Land costs and availability.
- Life expectancy of the storage structure.
- Cost, availability, and reliability of labor.

2. Engineering and Management Factors

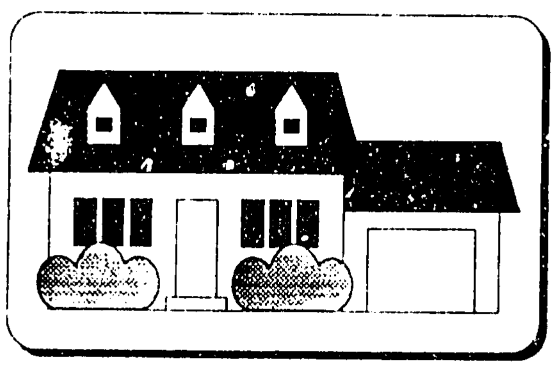
- Available grain handling, conveying, and transport systems
- Quality of locally available construction materials
- Frequency of filling and emptying of the storage facilities (monthly, seasonal, etc.)
- Availability of power supply and other utilities like water and communication.
- Prevailing harvesting, drying, and handling practices.

3. Grain Protection and Conditioning

- Feasibility to aerate and condition grain.
- Predominant stored grain pests.
- Ease of grain inspection and protection.
- Type of available pesticides and other pest control measures.
- Extent of insect resistance to chemical control measures.

4 - Ecological Factors

- Land tenure system and size of farms.
- If farming system is mechanized or labor-intensive.
- Number of crops grown per year.
- Types of grain produced in the area.



Comparison of Sack and Bulk Storage Systems

Sack Storage

- *flexibility of storage*
- *possible to mechanize partially*
- *slow handling capabilities*
- *low capital cost*
- *high potential losses due to rodents and other pests*
- *lower risk of losses due to*
- *moisture migration*
- *requires simpler operational skills*
- *allows co-mingling of products or varieties*
- *difficult to fumigate*

Bulk Storage

- *inflexible storage*
- *full mechanization possible*
- *rapid handling system*
- *high capital cost*
- *losses due to rodents and other pest is low*
- *risk of losses due to moisture migration*
- *requires highly*
- *skilled personnel*
- *grains lose their identity*
- *easier to fumigate*

REVIEW QUESTIONS

1. *Give the six basic requirements for grain storage.*

2. *What is the basic criterion in classifying a grain store to be flat or upright structure?*

3. *Give four basic advantages of a bag warehouse over a silo.*

4. *Why are silos preferred over warehouses for grain storage in more developed agricultural systems?*

5. *Describe the unique features of a Cyprus storage bin.*

6. *Give the advantages of using a portable grain handling system for a convertible godown. of fixed system.*

7. *When does a fixed grain handling system more cost effective over portable handling system?*

CHAPTER 9

STORED GRAIN PROTECTION

Insect infestation and spoilage caused by molds are the two major problems that a storage manager must deal with year round.

A. Problems in Grain Storage

Cereal grains are valuable source of food both for man and animals. They have outer and inner coverings that protect them from damage by ordinary handling. However, these protective coverings can not protect the seed completely from insect attack. Some insects can penetrate the covering and deposit their eggs in the grain. Other species of insects feed only on broken grains and processed products. Fortunately, in spite of their adaptability to their environment, there are physical factors that affect their activity such as temperature and moisture. They are active at certain ambient temperatures and grain moisture levels. Aside from these factors, there are chemicals that one can use in combating them. However, one should use chemical methods of control only as a last resort. As a rule, the use of preventive insect control measures are preferable over the use of corrective measures.

Another important aspect in the effective control of stored grain pests is knowing them and their characteristics This includes their life cycles, methods of reproduction, and how they attack grains. One should know the best temperature, humidity, and grain moisture at which they reproduce and do their most damage. This knowledge will greatly help those designing pest control programs and those who have influence in the design of storage facilities. A good pest control program must take into consideration pest characteristics and behavior. Similarly, a good storage structure should incorporate features that can keep rodents out and provide effective means of controlling pests.

B. Stored Grain Pests

There are three major species of animals that infest or attack stored cereal grains, namely: insects, rodents, and birds. In most instances, insects do more damage to stored grains than rodents or birds. This is because insects are not very visible to the untrained eye. They reproduce in the grain very rapidly if the conditions are favorable. Insects gain access to the godown through incoming stocks, fly in from nearby godowns, or crawl in from the outside.

1. <u>Insects</u> - There are four groups of insects that infest stored grains based on the nature and extent of their infestation. The four groups of stored grain pests are: **primary, secondary, incidental, and parasites** (Table 9.1). The main concern of a storage manager are the primary and secondary pests. Incidental pest become a problem only when stored grains have severely deteriorated. Some of the stored grain insects are considered major pests in some countries while the others are minor pests, or vice versa.

Primary stored grain insects complete their development inside a grain kernel. The adult female insect deposits its egg inside the grain. The egg will then hatch inside the grain and consumes the endosperm. Meanwhile, the secondary stored grain insects develop outside the grain. They can not penetrate sound grain kernels. For this reason, they lay their eggs outside the grain. The egg will hatch into a larva which feeds only on broken grains and processed cereal products.

Anybody involved in grain storage management must collect insect specimens in their godowns for identification purposes. This will greatly help in the planning of an effective pest management program.

Table 9.1. Common stored grain insects.

PRIMARY STORED GRAIN INSECTS

Common Name	Scientific Name
1. Maize weevil	*Sitophilus zeamais*
2. Rice weevil	*Sitophilus oryzae*
3. Granary weevil	*Sitophilus granarius*
4. Lesser grain borer	*Rhyzoperthadominica*
5. Angoumois grain moth	*Sitotroga cerealella*

SECONDARY STORED GRAIN INSECTS

Common Name	Scientific Name
1. Saw-toothed grain beetle	*Oryzaephilus surinamensis*
2. Merchant grain beetle	*Oryzaephilus mercator*
3. Cadelle	*Tenebroides mauritanicus*
4. Confused flour beetle	*Tribolium confusum*
5. Red flour beetle	*Tribolium castaneum*
6. Flat grain beetle	*Cryptolestes pusillus*
7. Rusty grain beetle	*Cryptolestes ferrugineus*
8. Khapra beetle	*Trogoderma granarium*
9. Indian meal moth	*Plodia interpunctella*
10. Mediterranean flour moth	*Anagasta kuhniella*
11. Larger grain borer	*Prostephanus truncatus*

These species have adapted well to live in most stored grains. They are responsible for most of the damage of grains in farm or commercial storage. Some species can survive with grain moisture below 9% while others become inactive below that level. It is important to recognize that some insects can survive extreme conditions. However, they require a certain range of temperatures and relative humidity to reproduce.

Another characteristics of some insects is that many are strong fliers like the *Sitophilus zeamais* and *S. oryzae* (maize and rice weevils). Other insects like the *S. granarius* (granary weevil) can not fly. The fliers can therefore move from store house to another on their own power. Other species can transfer from one place to another with the help of humans through the movement of the products they infest. The drawings in Figure 9.1 can help the storage manager in identifying the insects that may be present in his/her store.

a. *Life cycle* - Insects differ in their metamorphosis or life cycles. They all produce eggs but undergo different stages of development until they reach adult stage. Figure 9.2 shows an incomplete or gradual metamorphosis in some insects like a grasshopper. Meanwhile, Figure 9.3 shows a complete metamorphosis of an insect like the weevil. Most of the stored grain insects go through a complete metamorphosis. A knowledge of their characteristics is vital in planning a control program. The life cycle of some of the major stored grain insects is complete from egg to adult stage. The drawings in Figures 9.5 to 9.87 show the life cycles of the most common stored grain insects. It includes the unique characteristics and mode of eating that helps identify them.

b. *Insect reproduction* - Just like all living things, insects require an environment where they can breed and reproduce. The environment includes, food, moisture, and temperature. Their food and moisture source is the stored grain while the temperature comes from the surrounding air. If the conditions are right, insects can reproduce very rapidly thus creating serious problems to the grain storage manager or farmer. To demonstrate this relationship, the graphs in Figure 9.4 show the effect of moisture and temperature on the reproduction

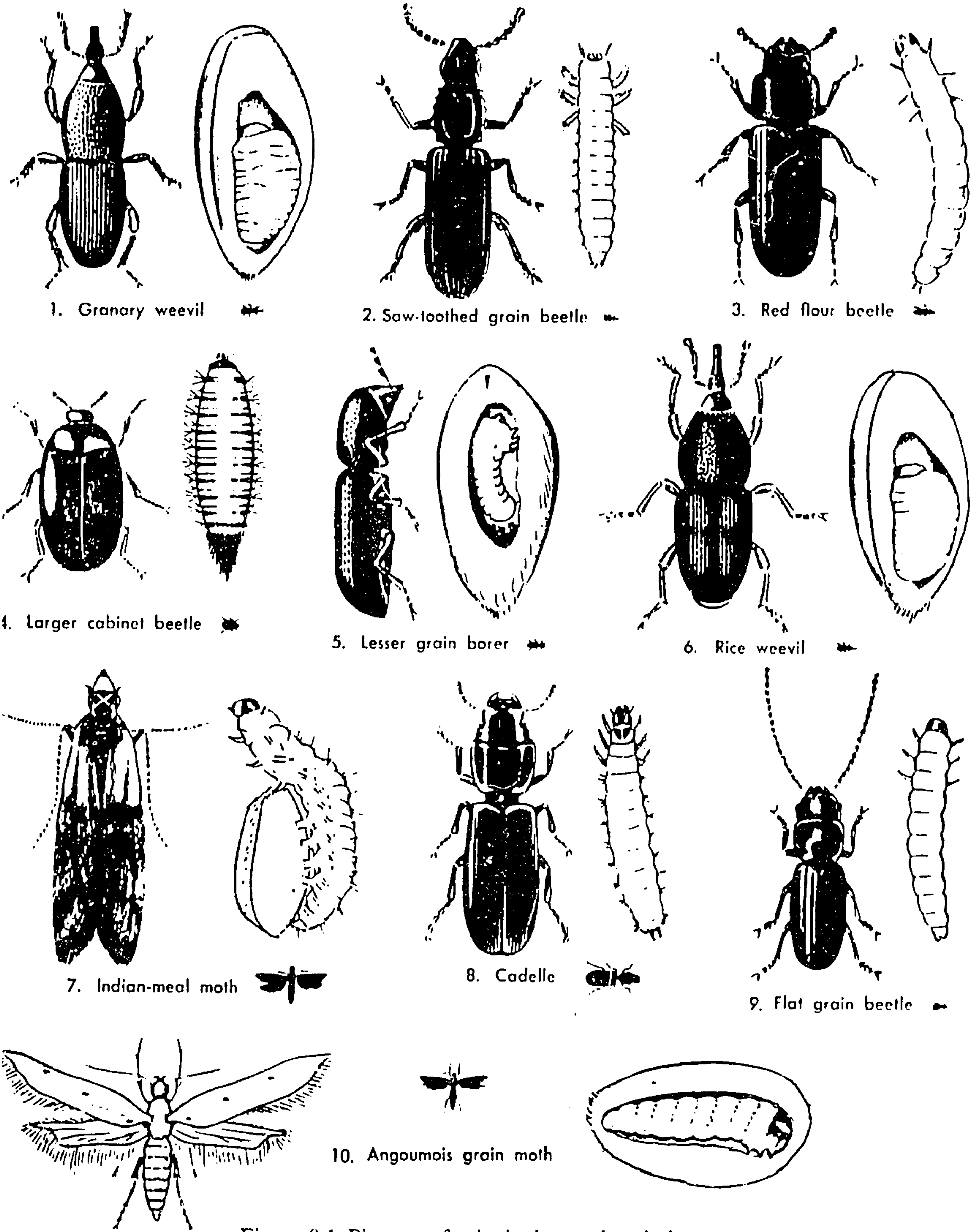


Figure 9.1. Pictures of principal stored grain insects.

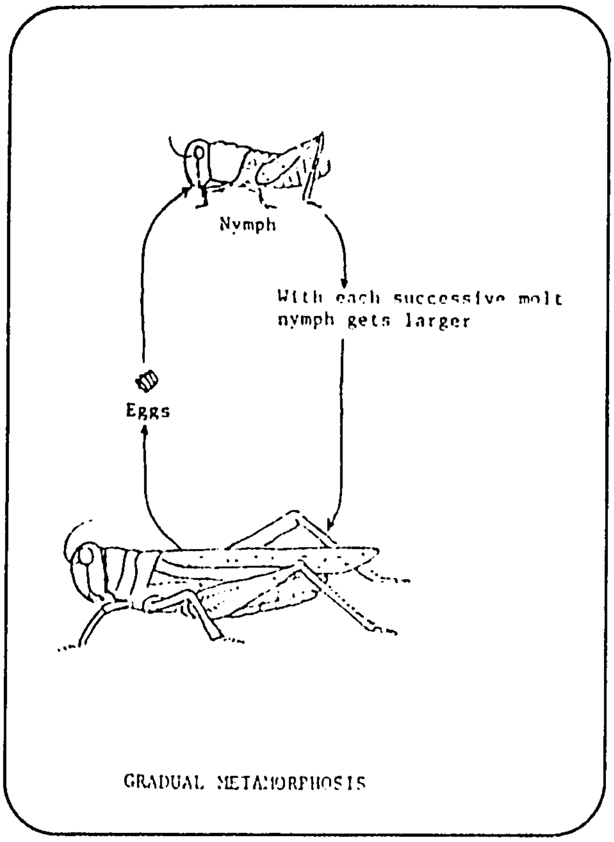


Figure 9.2. Diagram of an incomplete insect life cycle or metamorphosis.

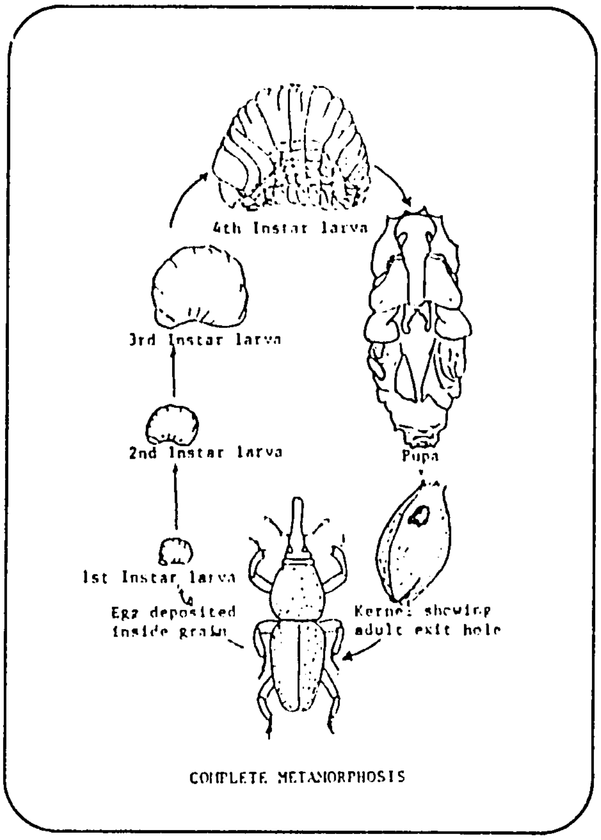


Figure 9.3. Diagram of a complete insect life cycle or metamorphosis.

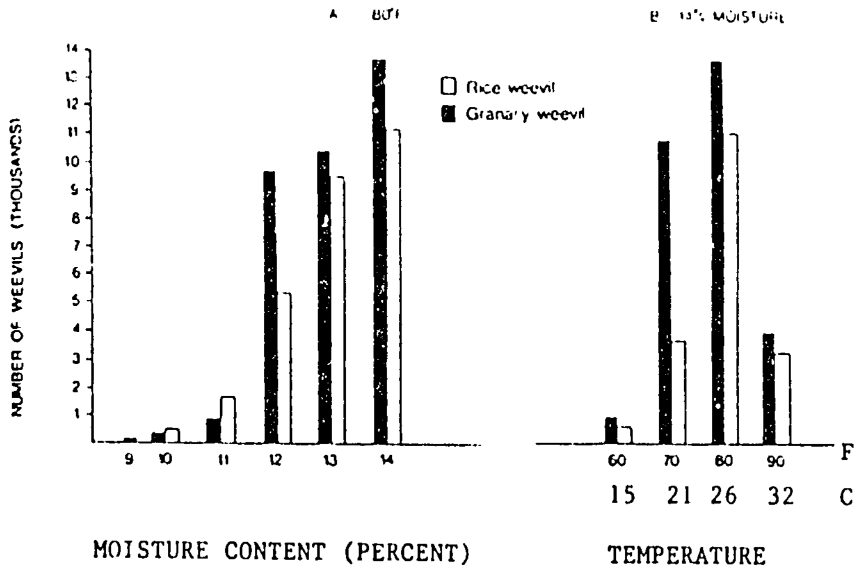


Figure 9.4. Reproductive rate of rice and granary weevils as influenced by temperature and moisture based on number of progeny after 5 months in stored grain.

Table 9.2. The days required to kill some stored grain insects with cold temperatures.

Insect	Days Exposure Required to Kill All Stages at						
	0-5°F	5-10°	10-15°F	15-20°F	20-25°F	25-30°F	25-35°F
Rice weevil	1	1	1	3	6	8	16
Granary weevil	1	3	...	14	33	46	73
Saw-toothed grain beetle	1	1	3	3	7	23	26
Confused flour beetle	1	1	1	1	5	12	17
Red flour beetle	1	1	1	1	5	8	17
Indian-meal moth	1	3	5	8	28	90	...
Mediterranean flour moth	1	3	4	7	24	116	...

*From Cotton (1950).

of 50 pairs each of rice and granary weevils based on number of progeny after 5 months. The warm and humid climatic conditions in tropical countries favor insect development and infestation.

2. Rodents - Rodents are among the vertebrate pests like birds that contaminate stored grains more than what they consume. Rodents spread human diseases. The most common are plague, murine typhus fever, and rickettsial pox.

They can spread these through their fleas or through their bite. In addition, rodents also carry or harbor diseases such as **Trichinosis, Leptospirosis**, and **Salmonella** through their droppings and urine.

Rodents are good climbers and can enter storage buildings through poorly fitted doors, walls, and windows. They are capable of jumping up to a height of 1 meter from the ground level.

They can easily enter warehouses by jumping into platforms of less than a meter elevation. People have observed them gaining access to a building through poles leaning on the roof and electric cables. They can climb drain pipes or down spouts or rough brick walls. Some species are good diggers and can dig through the ground and gain access to a building by gnawing through porous concrete. They have sharp teeth and can gnaw on soft bricks and adobe block.

a. *Common rodent species*

While one may find a number of species in a locality, there are three major species of rodents found in grain storage facilities. They are *Rattus norvegicus*, *Rattus-rattus*, and *Mus-musculus*.

(1) Norway rat, *Rattus norvegicus*

- Characteristics

Rodents have unique characteristics that distinguishes one from another. Most people call this species the Norway rat or sewer rat. Others call it the Common rat or brown rat. It is the largest of the three rodents mentioned above with gray brown or red brown fur. The

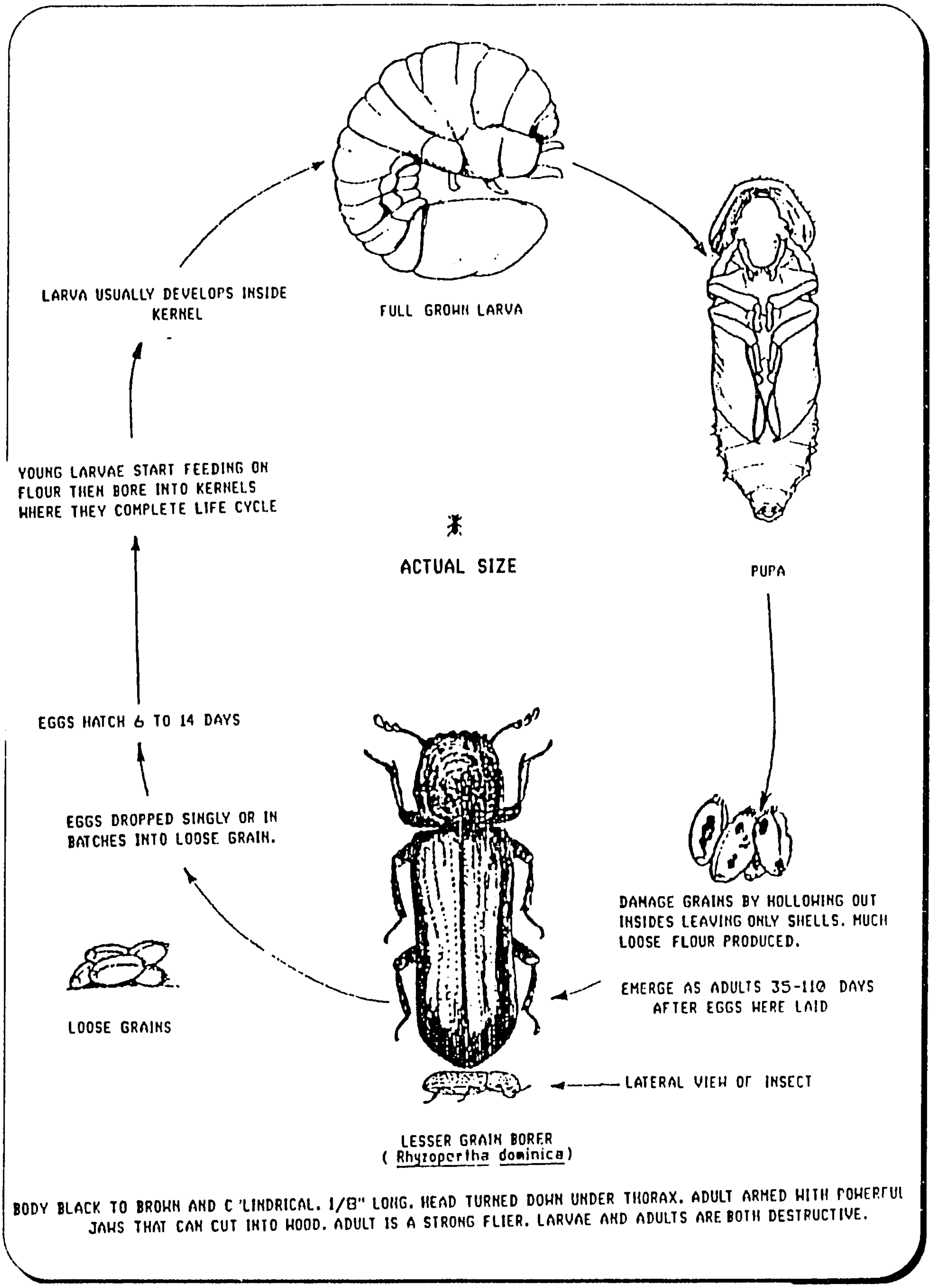


Figure 9.5. Life cycle of lesser grain borer

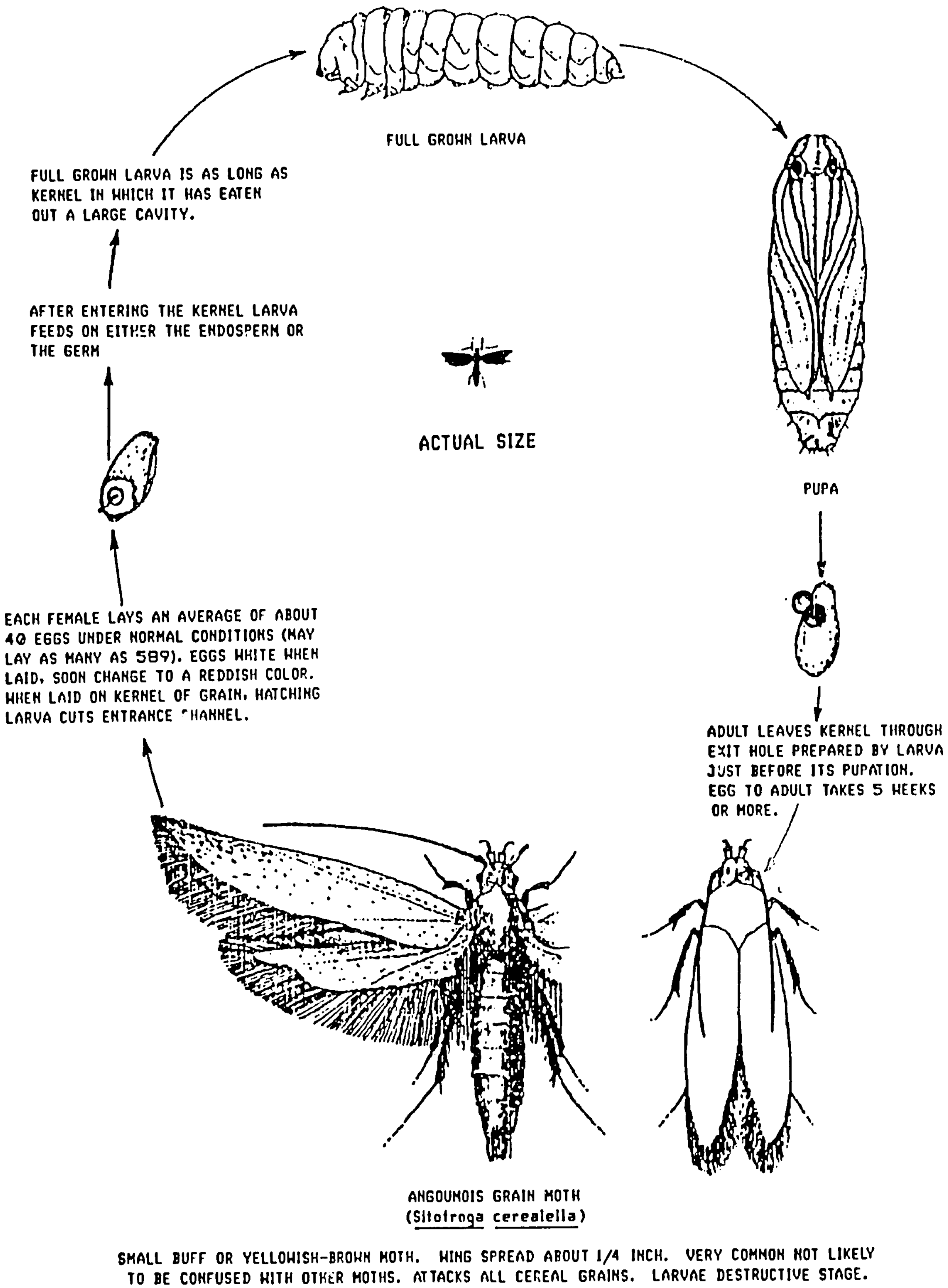


Figure 9.6. Life cycle of the angoumois moth.

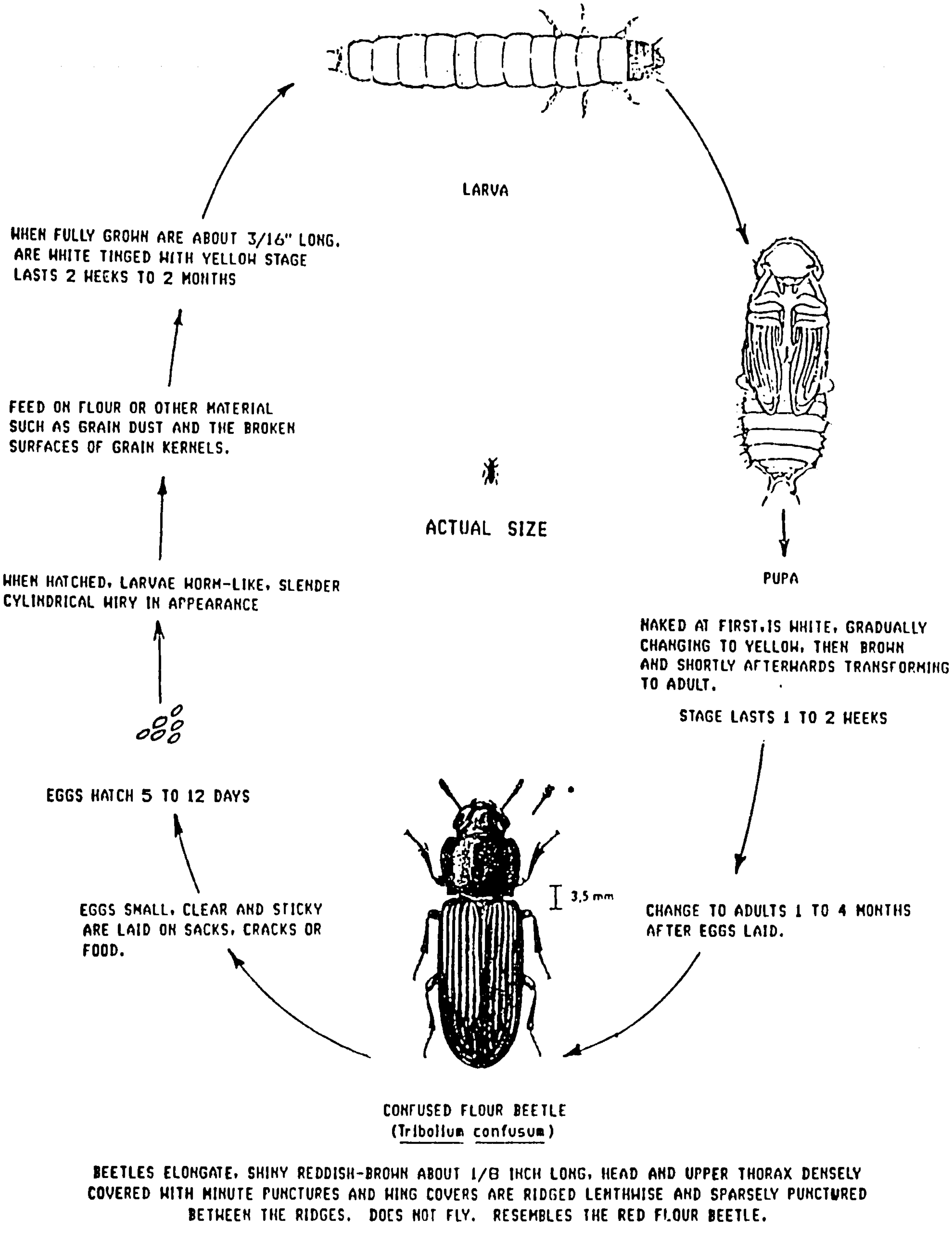


Figure 9.7. Life cycle of confused flour beetle

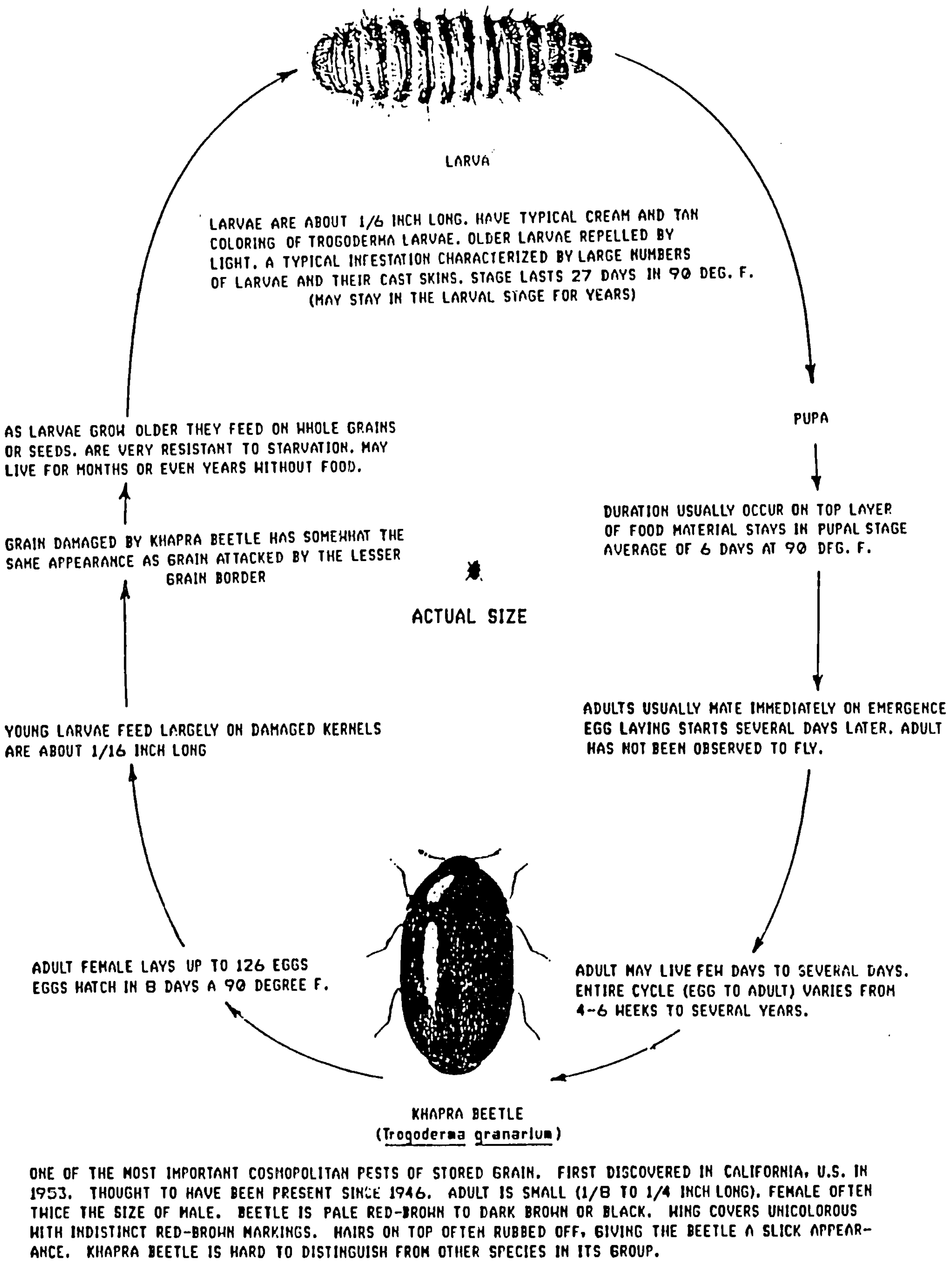


Figure 9.8. Life cycle of the khapra beetle.

adult rat is about 32-45 cm long and can weigh from 280 to 400 grams depending on available food. The nose is blunt, has small ears, and its tail is shorter than the combined length of the head and body.

They reach sexual maturity in 2-3 months and have a gestation period of only 23 days. A female rat can have 4-7 litters per year with 8-12 young rats per litter. Their life span is only about a year. They can rapidly reproduce with a female weaning an average of 20 rats. This rat lives in temperature climates close to human habitations. It is a very strong rat and aggressively looks for food in the field and in storage facilities.

(2) Roof rat, *Rattus-rattus*.

The common names of this specie are roof rat and black rat. Sailors call it ship rat or alexandrine rat. horticulturists call it the fruit rat. This rat is less dependent on humans. It survives better in tropical climates than the Norway rat. It dwells in store houses, homes and even in nearby forests. It is a very good climber and is agile on vines, can swim under water, and can jump. It has a very good sense of smell and hearing. It has a poor eyesight for distance but sensitive to changes in light and touch.

It is characterized by its long tail which is much longer than the combined length of the head and body. It weighs about 240-360 grams of total length of 34-41 cm. Its fur is black brown or rust color with long ears that stand out from the fur. Its life span is less than one year. A female roof rat can have as many as 4-6 litters producing 6-8 young rats per litter. Of these young rats 20 will survive. A roof rat reaches sexual maturity in 2-3 months and the gestation period is 22 days.

(3) House mouse, *Mus-musculus*.

It is the well-known tiny house mouse which weighs only 15-25 grams with a total length of 15-19 cm. It is a good climber and swimmer. The young ones can get through a 0.5 cm opening. They are nocturnal animals and most active at dusk. Seeing them at daytime usually means there is a large population in the area. They have a very keen sense of hearing and smell. They have poor distant sight like the roof rat. They use their whiskers to feel their way along walls and other objects during the day or night.

The life span of a house mouse is less than a year. A female mouse can have 8 litters per year producing 5-6 young rats each litter. Out of these 30-35 will survive. A house mouse can reach sexual maturity in 1 to 1-1/2 months with a gestation period of 19 days. The drawings in Figure 9.9 show some obvious characteristics of some rodents to help identify them from each other.

b. <u>Rodent signs</u>

Just like any living creature, rodents leave traces that confirm their presence in grain stores and other facilities. These traces are positive indicators of the extent of their infestation.

(1) Droppings or pellets.

The Norway rat has blunt pellets about 1.9 cm long. The Roof rat has pointed pellet about 1.25 cm long. The house mouse pellet is 0.65 cm long and pointed. Figure 9.10 shows a comparison of the sizes and shape of their droppings.

- <u>Urine</u> - Grains contaminated with rodent urine fluoresce under the ultraviolet light like grains contaminated with aflatoxin. To confirm the source of

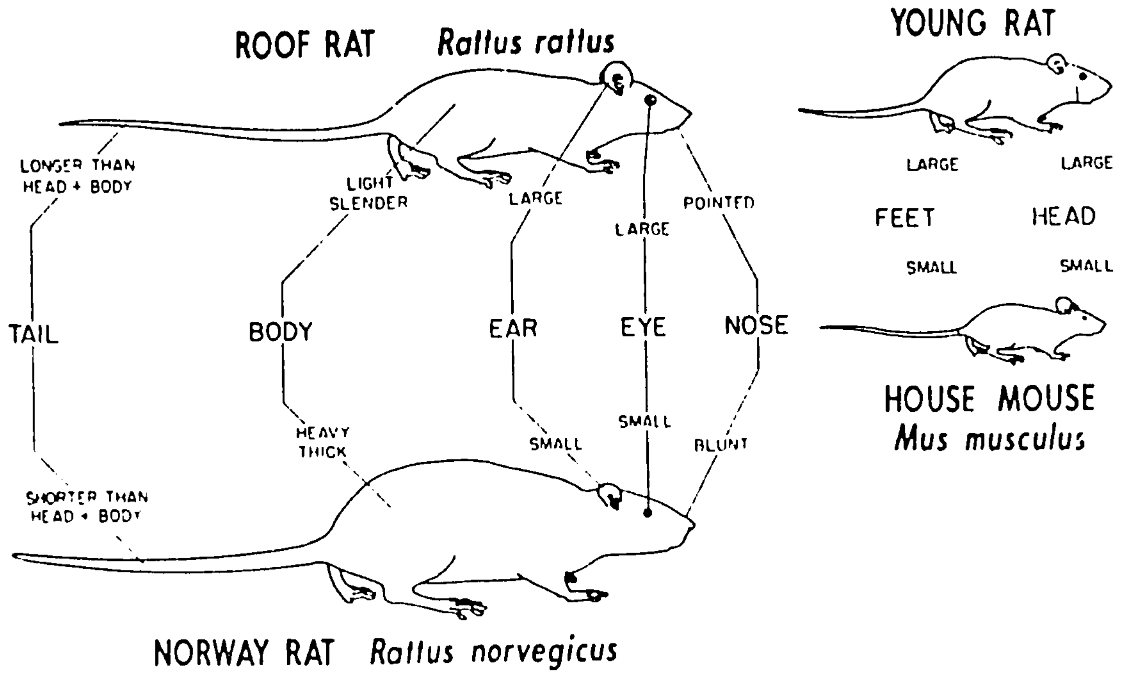


Figure 9.9. Distinguishing characteristics of adult and young rodents.

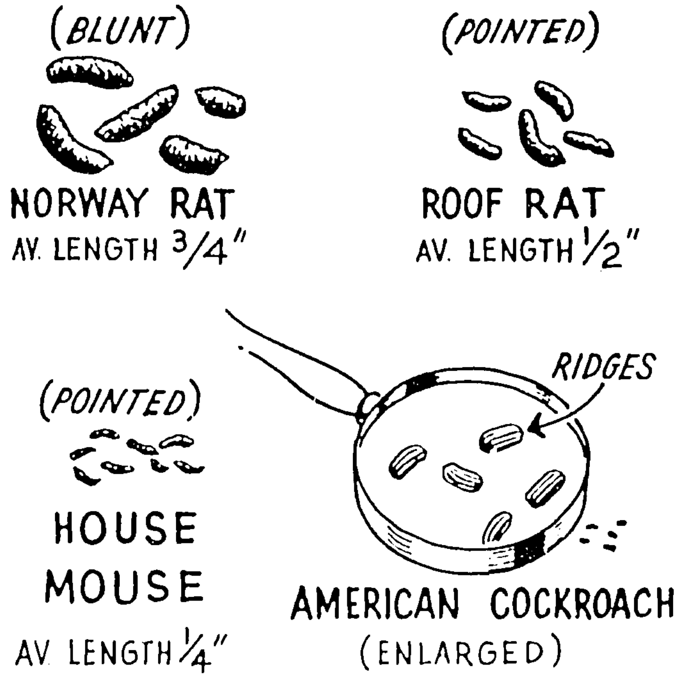


Figure 9.10. Comparative sizes and shapes of rodent droppings.

contamination, one should get a sample and have it analyzed chemically

- Gnawing - Gnawed objects like walls, packing materials, boxes, soft materials, including grains in the warehouse are evidences of their activity. Their gnawing ability is one of their means of survival. Gnawing also keeps their teeth from overgrowing

- Runways. - Rodents always use the same path in their search for food. They leave filthy smears from their body on walls and other surfaces they come in contact with.

- Tracks - Foot prints and tail marks are very common signs of rodent activity. One can detect the presence of rodents by spreading non-grain powder on store house floors. Their foot prints and tail marks will become very evident.

- Burrows - The Norway rat burrows next to buildings, walls, and concrete slabs The Annexes include information on rodents in Pakistan and practical control measures.

3. Birds

Birds consume grains that are still standing or left in the field. They swarm places where they can find spilled grains or grains spread in the open for drying. Some species make home in storage facilities such as on the ledges of buildings, ceilings, and ventilators. Birds usually contaminate more grains than they consume. They leave filth on the walls, ledges, and roofs of storage buildings. Their droppings contaminate stored grains and may carry diseases like leptospirosis, histoplasmosis, elephantiasis, coccidiosis, and salmonella Nests and carcasses are sources of dermestid beetles like the *Trogoderma sp.* and mites.

C. Control Methods

The two methods of controlling stored grain pests are physical and chemical methods.

1. Physical methods. - Physical control methods include the following practical measures:

a. *Use of high temperature*

Most stored grain insects are active only at a certain temperature range. Near or below freezing and above **60 degree Celsius** most stored grain insects become inactive or get killed. Table 9.2 gives the survival of some insects at various extremely low temperature levels.

b. *Drying of grain to very low level*

Most stored grain insects can subsist on moisture levels above 9%. Below this level, majority will die while a few species will go into hibernation or inactive state.

c. *Sanitation and housekeeping*

This is the safest and the least expensive method of pest control. While this is so, most grain storage managers take it for granted and usually handle their grain stocks like inert materials.

d.. *Barriers*

Physical barriers such as screens are effective in controlling birds and rodents. Making closely fitted doors can keep rodents out of a storage building. Another effective barrier is to elevate the floor of a storage building about 1 meter above the ground level. There are other physical methods of pest control such as irradiation and steaming. However, they are not practical to use under normal storage conditions.

2. Chemical control - These control methods include all the insecticides, avicides and rodenticides that kill either insects and vertebrate pests. However, all are also harmful to humans and require careful use to avoid possible death or ill effects to workers.

a. *Insecticides*- They are chemicals of various formulations that poison or kill insects. The use of fumigant to control insect infestation is very popular in many developed and developing countries. However, the improper use of fumigants has let to the emergence of resistant strains of stored grain insects. For this reason, better techniques of fumigation are now available. The PARC in collaboration with the Storage Technology Development and Transfer Project has developed techniques of fumigating godowns, bag stacks, bulkheads, hexagonal bins, and silos. The PARC reports in Annex C and D present simple grain protection techniques appropriate for developing countries like Pakistan.

b. *Rodenticides*- They are chemical preparations that poison or kill rodents. A comprehensive manual on rodent control is available from the PARC Vertebrate Pest Control Project.

c. *Avicides*. They are chemicals that poison or kill birds. A thorough knowledge of the properties of pesticides and how to use them is vital in using them effectively and safely.

REVIEW QUESTIONS

1. *Give the difference between primary and secondary stored grain insects.*
2. *Which species of insects are prevalent in your locality?*
3. *What characteristics do rodents have that allow them to enter storage buildings?*
4. *Why should one be concerned with rodents and birds beside the problem of grain they consume?*
5. *What method of pest control is the most effective? Why?*
6. *How does Aluminum Phosphide produce the deadly phosphine gas that kills both insects and vertebrate pests?*
7. *What safety precautions must one observe when using pesticides?*

CHAPTER 10

GRAIN GRADES AND STANDARDS

Grain grades and standards are just communication tools that users must understand and practice to make it work and useful.

A. Background

Batches of grain whether in bags or in bulk are rarely uniform in physical composition. Grains as they come from the field are basically an admixture of plant and non-plant materials. The plant and field conditions affect the quality of the grain. The same grain after harvesting will have variation in grain moisture and maturity. The harvesting and subsequent handling operations will further add to the variation when the grain reaches the market.

B. Grain Quality

Quality refers to the "suitability for a specific purpose." Buyers and sellers normally know the characteristics of grain that provide the type of end products they require (i.e., atta, maida flour, and other wheat based items). Experienced buyers can assess the suitability of grain for their particular needs by visual inspection. With growing volumes of business, it is not possible for large scale buyers to examine every lot offered for sale. These buyers must rely on specification of grain that describe the physical characteristics important to them.

Grain quality has different meanings to different people. Quality may mean high milling yields to a flour miller or good baking characteristics to a baker. It may mean a high yielding variety to an agronomist or protein-rich grain to a feed miller. There is no single wheat that meets the requirements of all the users. That is why there are varieties and classes of wheat for different purposes. There is a wheat variety that is good for making noodles and another variety that is good for making chapati. Similarly, there are types and varieties of other grains and oilseeds. For example, white flint corn is best for making the "tortilla bread" of Latin America while yellow corn is good for feed formulation. Figure 7.1 shows wheat types of and the products made from them.

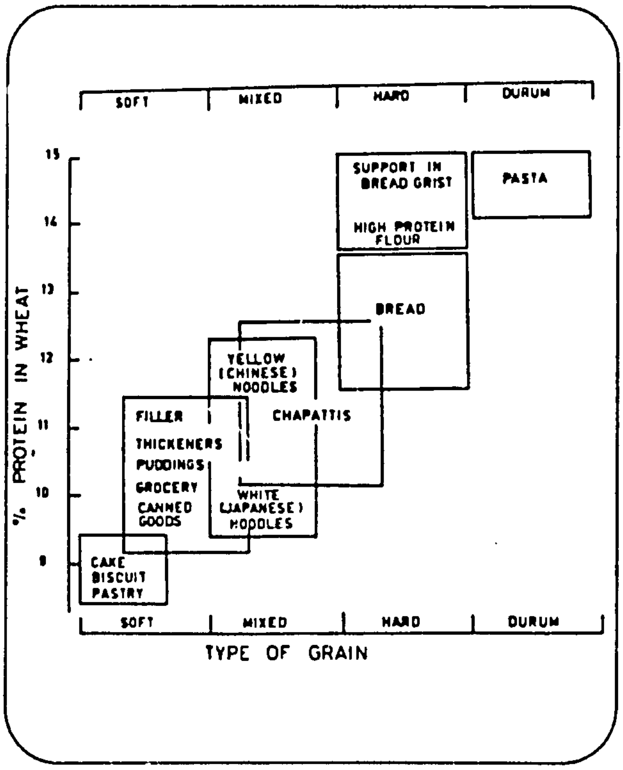


Figure 7.1. Wheat types and types of products made from them.

C. Establishing Grades and Standards

Over time, the industry will summarize the qualities buyers want in grains into a few words describing what is wanted or available.

Governments often adopt the terminologies used by the market as official standards. Meanwhile, Grades are subdivisions or subsets of the standards. Grain grading is the physical measurement of grain characteristics against the standards to determine its grade.

To conduct any quality evaluation, grain traders must first establish grain standards and grades. For instance, grain moisture content affects the milling characteristics and how long one can store grain safely. The measurement of moisture content will permit the buyer to know if a lot of grain meets their needs. They can calculate how much it will cost to prepare the grain for making the desired end products. If majority of the buyers want low moisture content, grains with the low moisture will be "Grade A" or "No. 1." Grains with higher moisture levels will receive appropriate numbers or letters indicating lower grade designation

In the grain moisture example above, buyers and sellers must agree that moisture content is important. The quantity of moisture present establishes the grade as it relates to storage and processing. For example, grains with moisture content of 8.0 to 9.9 percent could meet the requirement as "Grade A". Grain with 10.0 to 11.9 percent would receive a designation of "Grade B", and 12.0 percent or more will be "Grade C "

Normally, buyers are interested in other properties of grain in addition to moisture. Other important factors are the extent of kernel damage caused by insects, mold, or mechanical devices. Kernel size, color, and chemical composition are equally important factors. The quantity of non-grain materials accompanying the grain is also important. Pre-cleaning normally removes these foreign matters or non-grain materials Cleaning removes other grains before processing. Their presence in the grain decreases overall milling yields and increases unit cost. Hence, millers prefer to buy clean and wholesome grain over buying dirty grain. Thus many factors comprise a grain standard and a grain grade summarizes a weighted set of factors into a single letter or numerical designation.

D. Assessing the Grade

The industry must simultaneously establish equitable grades and standards and quality assessment procedures that are practical and reliable. Anyone who does grain assessment job must use the same procedure and standard set of equipment in determining grain grades. To complete the system of grading, there must be a cadre of well trained and licensed personnel to grade and inspect grains. There must also be an agency to enforce the grading system. The last requirement is perhaps the most difficult to meet in many developing countries.

Even after establishing its grading system, the grain industry must constantly evaluate its grades and grading procedures. This is to keep abreast with changing technology in grain grading, handling, processing, and storage. For instance, electronic devices for measuring moisture content, protein, color, and sizes of grain kernels are becoming less expensive and more reliable. Industry should determine the need to change a part or the whole system to reflect the effect of new technologies. Any changes in the system will depend upon its importance to processors and consumers alike. Are they willing to pay or not for a more precise definition of the product qualities they want? Other considerations are time and the cost to make the changes and how long they are likely to remain in effect.

E. Importance of Grades and Standards

One may understand the significance of the system of grades and standards by considering a scenario where none exist. Without any grading system, producers and grain merchants feel free to mix grains regardless of quality or variety. Grains traders blend grains with different moisture content and soundness. Sellers bring grains of unknown quality to traders who buy all and make no distinction between quality or varieties of grains.

The lack of grain grades and standards discriminates against the producers of high quality grains while rewarding those with poor quality grains. Where no grading or standards exist, there is a tendency for all grains to sink to the lowest quality acceptable by the market. Buyers will lower their price offers because of the unknown grain attributes that may require additional processing to meet their requirements.

Blending occurs naturally at the farm level and at collection centers. It occurs at village markets and at urban buying stations. Blending thus creates large volumes of grain commonly known as fair average quality (FAQ). The FAQ is a standard that purports to represent the average of what is available in a given market area.

Processors have the enormous task of cleaning and sorting the grain. They may choose to clean or not to clean the grain. If they do not clean, the sand and foreign materials will ruin their mills. Unreliable product quality drives customers away. To avoid this from happening, processors have to invest in elaborate grain sorting and cleaning systems. The cleaning and sorting operations reduces the overall milling recovery and potential profit.

The milling industry produces only one kind of flour because there is only one type of wheat available. Millers increase the price of the finished product to recover their losses in the quantity available for sale.

Consumers with higher incomes demand better products, but do not find them available in domestic production. They switch to other products or buy imported goods. The country losses foreign exchange on the importation of products that otherwise local entrepreneurs can produce locally. Farmers lose potential markets for their grain and suffer from lower prices.

To keep the price of the flour down, the government subsidizes the cost of the wheat and fixes its prices. The government must provide subsidies to keep food prices low for urban workers and ensure political stability. The cause and effects of the lack of grades and standards on an economy is inestimable. There are costs and benefits in supporting a grading system. However, the over all consequences and costs of not having a system will surely be much higher.

The above scenario is a dramatic over-simplification of what can happen without grades and standards. However, it sounds all too familiar in many developing countries. For the above reasons, many countries have long recognized the consequences of the above scenarios. They have evolved their own grades and standards out of a desire to provide orderly and progressive markets for producers and consumers. Grain grades and standards vary from country to country and from continent to continent.

Many developing countries established their grades and standards based on the standards of a country with whom they have strong economic ties. There is a danger in the blind adoption of another country's standards. A country must give consideration to the attributes of its locally produced grains, the end products, processing methods, local customs, and traditions.

In colonial times, the major grain consuming and producing areas of Pakistan had a local grain exchange or board of trade. Major grain exchanges existed in Lahore, Multan, Faisalabad, Okara, and Karachi. Each exchange had its own grading system, and the FAQ buying standards used today originated in these grain exchanges. Traders used FAQ to describe the quality of wheat that was available in the area covered by the grain exchanges. The FAQ described the quality of wheat a seller will deliver at some future date to buyers in other cities or distant locations. A paper in the Annex discusses FAQ and wheat quality in more detail.

Today, some countries are still struggling to develop their own grades and standards. This is not surprising because it takes science and technology to establish grain grades and standards. One can not over-emphasize the importance of education in the adoption of a new technology. Education can be formal or informal. A country must educate its people on the costs and benefits of having a system of grain grades and standards.

The public needs education to understand how the system works and be able to recommend changes as appropriate. Any system will fail if the grades and standards permits one segment of the economy to gain undue advantage over the other. A system of grain grades and standards must be impartial and enable all groups to communicate freely with each other. This is where the need for training and extension activities come into focus. A country that has no way of extending new technology systematically to its people will be at an extreme disadvantage. The ability to exchange points of view is necessary to overcome deeply rooted socioeconomic obstacles in establishing a modern trading system. A free and dynamic mass media can help attain the above goals.

F. Grade Factors and Their Importance

The grading of grains requires a knowledge of its <u>inherent</u> and <u>acquired</u> traits or characteristics (Table 10.1). The kind or class of grain fixes the inherent traits while preharvest and postharvest processes impart the acquired traits. It is the job of grain graders to distinguish between the inherent and acquired characteristics of a grain sample. Grain graders must also determine if grains as examined fall within acceptable limits according to established grades and standards. This is why a knowledge of the attributes of locally produced grains is very important. A cooperative research work between research institutions and industry can help establish inherent and acquired characteristics of locally produced grains. The above grain attributes can fall into four main categories, namely: <u>type of grain</u>, <u>soundness</u>, <u>purity</u>, and <u>special characteristics</u>.

The grading of grains require a minimum set of grain testing equipment. These equipment should provide a means of making consistent and reliable analyses. For example, a good electronic moisture meter can provide quick measurements of grain moisture consistently and accurately. Similarly, one can use a dockage tester that can determine the purity of a grain sample accurately and repeatedly. However, one still need years of experience to grade a sample based on other grade factors like kinds and classes of grains (Table 10.2). That is why graders keep <u>standard grain samples</u> for comparison in

TABLE 10.1. EXAMPLES OF INHERENT AND ACQUIRED TRAITS OF GRAINS USED IN GRADING :

Inherent	Acquired
1. nutrient content	1. texture (shriveled)
2. hardness	2. odor
3. shape	3. fissures
4. size	4. brokens
5. color	5. bleached color
6. smell	6. mold damage
7. germinating capacity	7. other traits

determining classes and other special grain traits. Table 10.3 is a proposed grading table for wheat in Pakistan with the maximum limits of the various attributes.

Grain inspectors and graders in developed countries undergo intensive training and get licensed before they can do any grain grading work. The success of a grain grading system depends on the integrity of the agency charged with the implementation of the system. The grain trade needs an independent and impartial third party to maintain public confidence in the grading system. The Federal Grain Inspection Service (FGIS) in the United States has fulfilled that role.

The FGIS regulates and performs grain inspection and grading in the United States. The U.S. Government established the FGIS in the 1940's to serve both the interest of sellers and buyers of grains The FGIS is completely immune to political influence or pressures in carrying out its function. It also trains and licenses grain graders or inspectors from the industry and from any State of the Union.

An agency that can perform grading and inspection services impartially is nonexistent in many developing countries. A smooth flow of trade between countries requires mutual trust and respect. Buyers and sellers must have confidence in receiving their deliveries and payments based on the specifications in their sales contracts. It is not possible for every buyer and seller to examine each lot of grain prior to delivery. All too often less developed countries trade with distant developed countries even if a nearby developing country can supply their needs. Grain trade between neighboring countries usually do not occur because of bad experiences in the past. This is because of the lack of an acceptable grades and standards and a system of enforcing it.

TABLE 10.3. THE MAJOR ATTRIBUTES OF GRAINS THAT ESTABLISH GRAIN GRADES AND STANDARD

- Kind of grain (corn, wheat, etc.)
- Class (yellow, hard red, etc.)
- Damaged grain (heat, mold, etc.)
- Foreign material (dust, stones, other food grains, etc.)
- Dockage (plant material from same grain)
- Broken (1/2 size, split, etc.)
- Test weight (lb/bushel or kg/hectoliter)
- Other features (opaque, winter, spring, etc.)

G. Minimum Grading Equipment

Grain graders and inspectors need a minimum set of equipment to perform their jobs (Table 10.2). Figure 10.1 shows typical laboratory grain testing equipment that the grain industries in most developed countries and developing countries use.

Table 10.3. A PROPOSED GRAIN GRADES OF WHEAT IN PAKISTAN

Factors Applicable	Values applicable		
Moisture Content %	Upto 9.0	> 9.0 to 10.0	> 10.0 to 12.0
Foreign Matter %	0 to 0.5	> 0.5 to 1.5	> 1.5 to 2.5
Broken & Shrivelled %	0 to 1.5	> 1.5 to 2.5	> 2.5 to 5.0
Other Food grains %	0 to 1.0	> 1.0 to 2.0	> 2.0 to 5.0
Damaged % grains	0 to 0.5	> 0.5 to 1.0	> 1.0 to 2.0
Quality Grade	A	B	C

Table 10.2. SAMPLE LIST OF GRAIN TESTING EQUIPMENT

- Set of sieves and pans
- Scale or balance
- Bulk density tester
- Moisture meter
- Magnifying glass (lens)
- Grain samplers, spears, probes, etc.
- Sample divider
- Tweezers
- Sample bags or containers

H. Importance of Representative Sampling

A grain grader can determine the quality of a sample using standard grain testing equipment and procedures. He can express the results in precise terms and figures. However, the results may be meaningless unless the grader analyzed a representative grain sample. Random sampling is a procedure of getting representative grain samples. It is a method of getting samples such that each sample has the same chance of being taken or drawn.

As mentioned earlier, a mass of grain is an admixture of plant and non-plant materials. For this reason, grain inspectors must gather representative samples by randomly drawing grains of predetermined quantity from a grain lot. Any sampling procedure other than random sampling is a biased or none-representative sampling procedure. For example, one can not draw random samples from a stack of bagged grain without first dismantling the stack. Likewise, one can not draw representative samples from a truck-load of bagged grain without first unloading the bags. Very often, grain inspectors draw samples only from the periphery of a truck load of bagged grain missing completely the inner bags.

Random sampling is therefore a very important ingredient in the successful application of any grain grading system. This

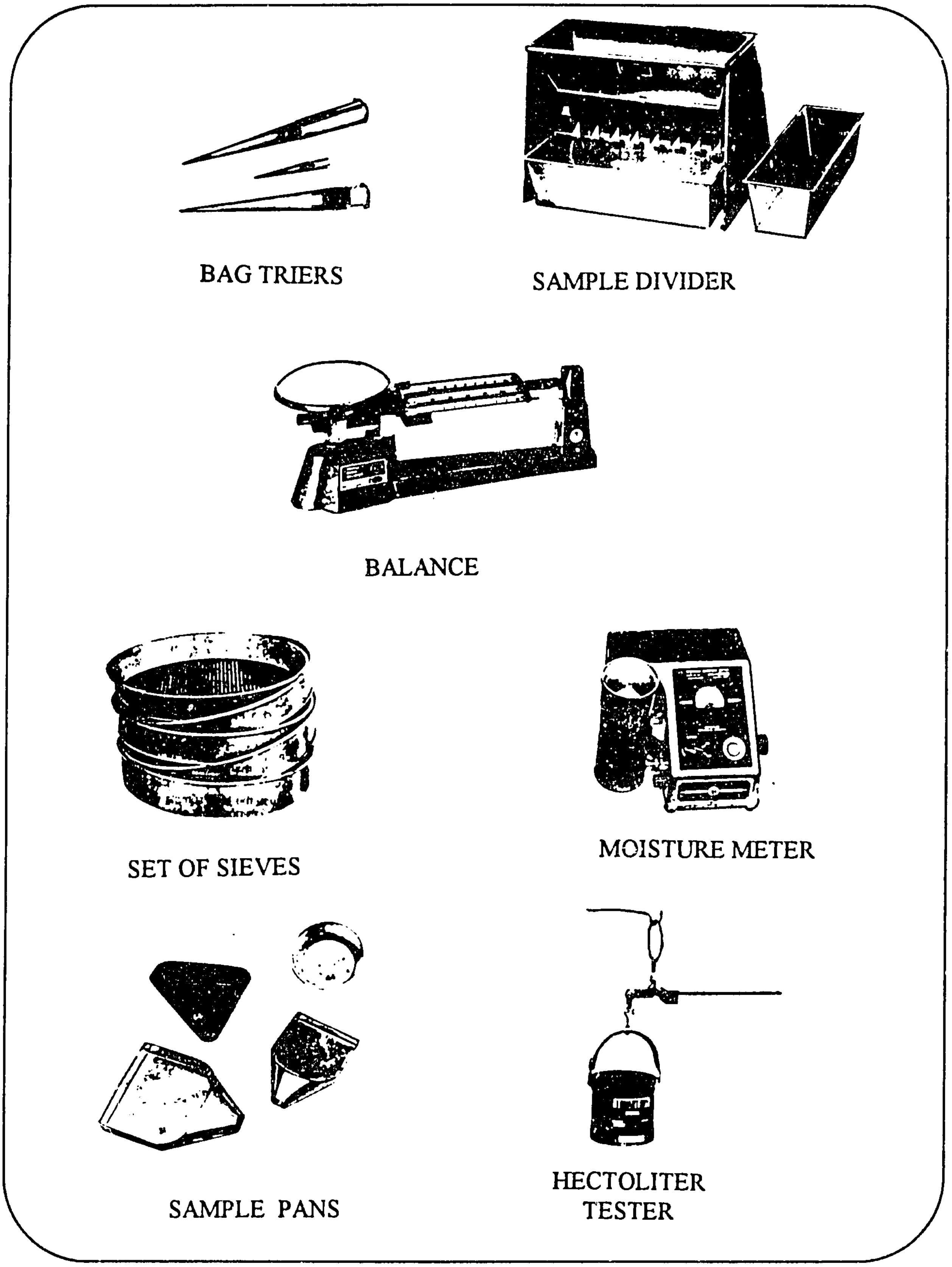


Figure 10.1. Pictures of typical grain testing equipment used in the grain industries of both in developing and developed countries.

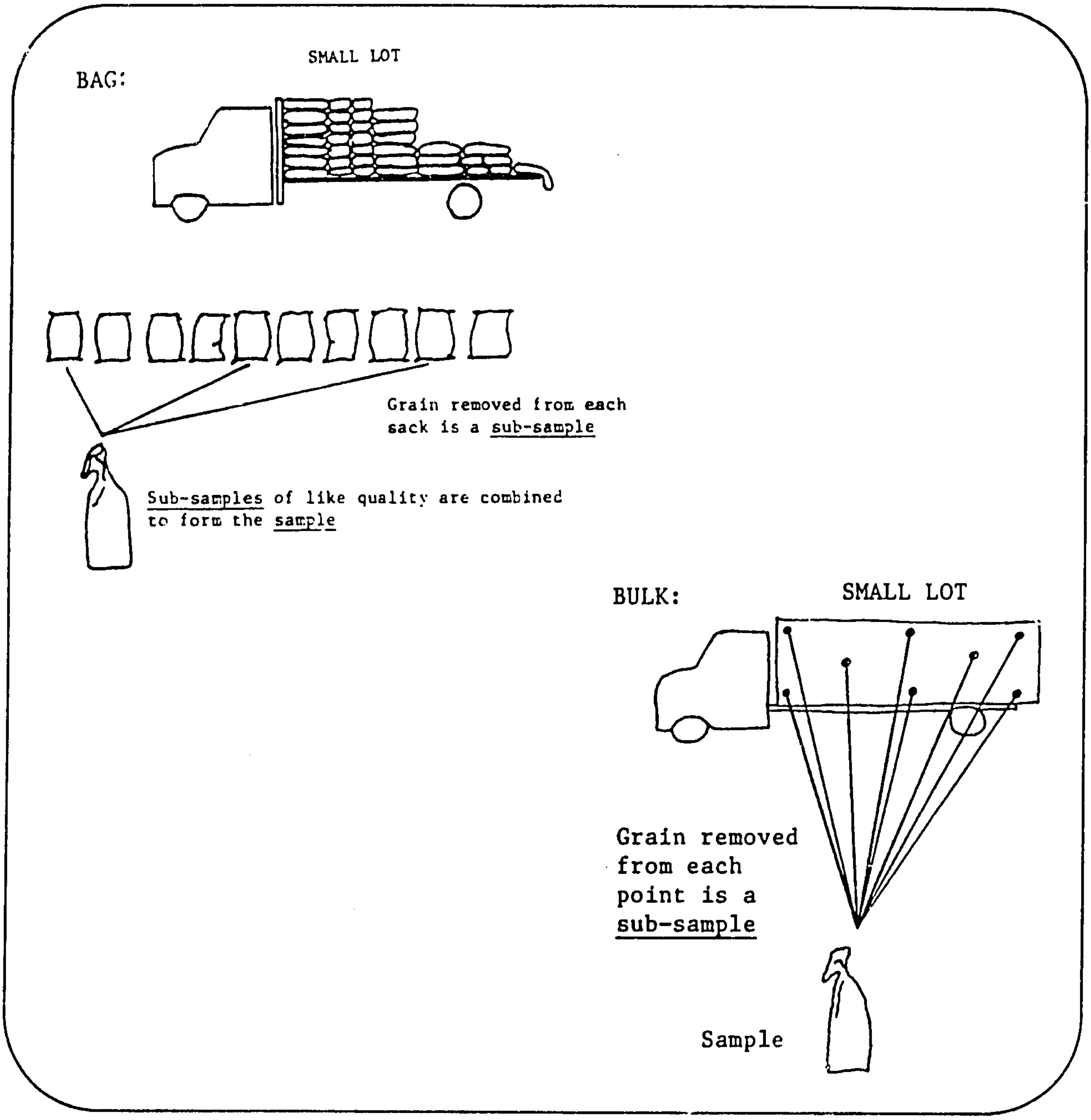
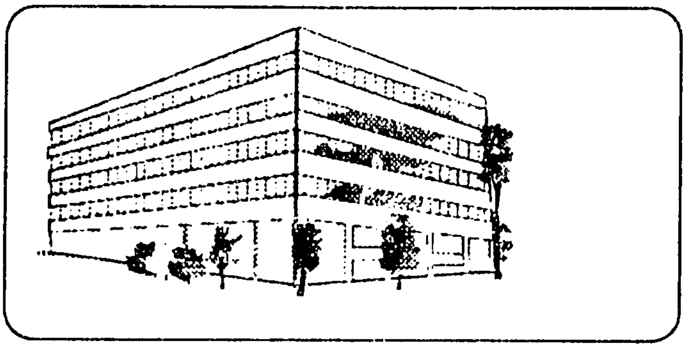


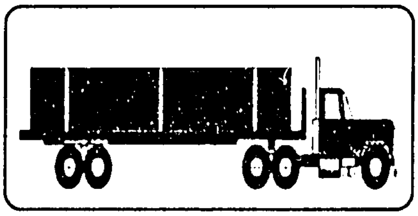
Figure 10.2. Random sampling of small and large lots of bagged and bulk grain.



procedure helps gain the confidence of all individuals and discourages dishonesty in the storage and the marketing of grains. Annex E discusses more in detail about the importance of grain grades and standards specially for wheat and Pakistan.

REVIEW QUESTIONS

1. *What are the advantages and disadvantages of not having grain grades and standards?*
2. *Give the four categories of grain attributes that graders use in establishing grain grades and standards.*
3. *Explain what random sampling means.*
4. *Why is representative sampling important in grain quality testing and grading?*



CHAPTER 11

GRAIN MARKETING

Marketing is the bridge between producer and consumer involving many activities regardless of social and political boundaries. It involves functions such as assembling, storing, transport, grading, buying and selling.

A. Market System

The grain marketing systems in more advanced agricultural economies are characterized by collective sale of grains from the farm to the open market. The chart in Figure 1.1 shows this grain marketing system. The farmers market their grains through cooperatives societies and through large grain corporations. These corporations usually have buying points in major cities. Traders also sell grains in the open market through a "Board of Trade" which operates like a "stock exchange". Most producer societies (cooperatives) and buyers (millers, exporters, etc.) conduct their grain business through this system. They may also trade directly among themselves. Some farmer cooperative societies are affiliated with a large grain company. These large grain companies market grain both for domestic and export purposes. The large grain companies influence the flow of grains from the farm to the market.

The situation in most developing countries is entirely different. In these countries, the government through a marketing board usually controls the trading of domestic as well as imported grains (Fig. 1.2). The Marketing Board sets the price of the grain to protect both the consumer and the producer. It buys about 20 - 30% of the locally produced grains and stores it in its own storage facilities as food reserve. Meanwhile, the middlemen buy the remainder of the local grain and sell it to feed manufacturers, flour millers, and grain traders. The middlemen play an important role in the entire grain marketing system in most developing countries They usually own a fleet of trucks of varying sizes. Sometimes, they extend production loans and other farm inputs to small farm owners at exorbitant interest rates. This condition enables the middlemen to buy the grain at a low price immediately after harvest. The price paid by middlemen is usually lower than the support price announced by the government.

To free the farmer from the control of the middlemen, governments have tried in the past to organize "farmers cooperatives." These farmers' cooperatives provided production loans and marketing services to their members. Many were patterned after western models complete with financial support and governmental backing. However, many of these cooperatives failed mainly because of dishonesty and lack of management capabilities among its officers and members. However, there are exceptions like the many cooperatives that succeeded in Taiwan, Korea, and Thailand. Many of these cooperatives have become models for other developing countries to follow. It is not surprising that these countries are now among the most progressive countries in the region.

B. Marketing Function

Producing of grains is only part of the job. These grains must be transformed into products when and where they are needed by consumers.

This is the task of marketing. In economic terms, marketing creates utilities or values for which consumers are willing to pay. The primary marketing utilities are *time*, *place*, and *possession*. Most text books add a fourth utility - *form*, but are divided over whether the form utility is included in marketing. Virtually everything produced requires some change or transformation before it can be consumed. Wheat must be made into atta or flour, thence into chappi or bread before it can be assimilated by the human body. Other grains may be made into poultry or animal feeds - then fed and converted into meat, eggs, poultry, milk, ghee, etc. Each of the transformations or conversions require skills, capital investments, and time. Consumers pay for these services also.

Time utility is created by storage, place utility by transportation, and possession by exchange of goods for money or other items of equal value. In the ordinary course of events, performance of these utilities is not complex or difficult. As the volume of trade and distances involved increase, performance becomes increasingly complex. A producer bring and selling wheat to the local chakki mill has performed the time, place, and possession functions in their most elementary form. one question that remains is how the price is determined. This will be explained in the following section.

The grain marketing systems in the more advanced agricultural economies is usually characterized by collective sale of grains from the farm to the open market. The chart in Figure 11.1 shows this grain marketing system. The farmers market their grains through cooperative societies or through large grain corporations. These corporations usually have buying points at strategic rural locations and in

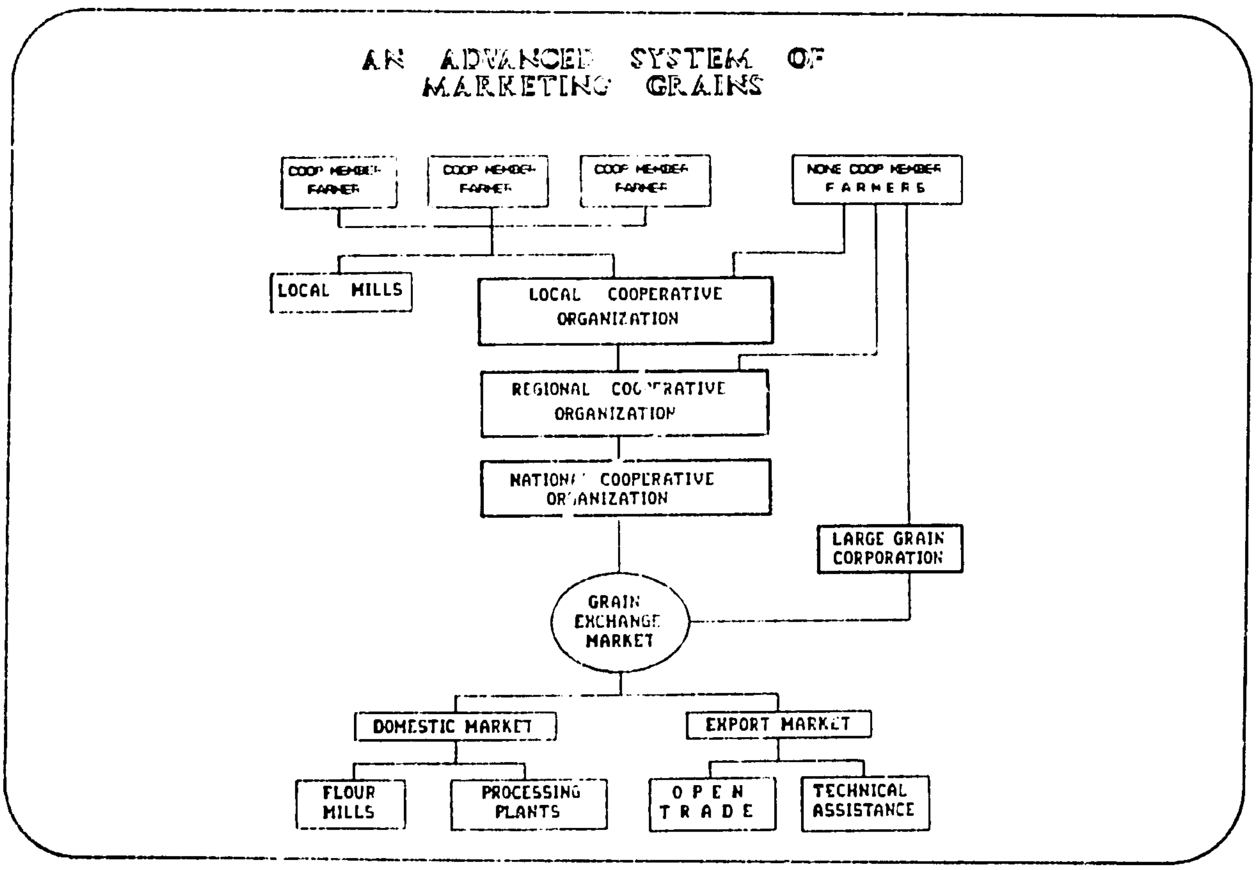


Figure 11.1. Grain marketing system in many developed economies.

major cities. The top level of the trading hierarchy is a grain exchange. In colonial times, Pakistan had grain exchanges in Lahore, Karachi, Hyderabad, Multan, and Llylpur (Faisalabad) as well as in major grain areas such as Okara, Gujaranwala, and Sahiwal. In western countries, grain exchanges are known as a Board of Trades which operates like a stock exchange.

The situation in most developing countries is different. In many such countries, the government intervenes in markets by assuming many of the marketing functions (Figure 11.2). Often a Marketing Board, similar to the Provincial Food Departments, sets the price of the grain to protect both the consumer and the producer. Control of 10% to 15% of the market supply is required volume to influence the markets. The Government must stand ready to buy and sell at announced prices at any time to maintain its pricing goals. Knowing when and where to intervene requires considerable skills to achieve a government's economic and social objectives. Middlemen buy the remainder of the local grain and sell it to feed manufacturers, flour millers, and grain traders. The price and amount of control middlemen exert on producers and markets depends upon proportion of the market supply

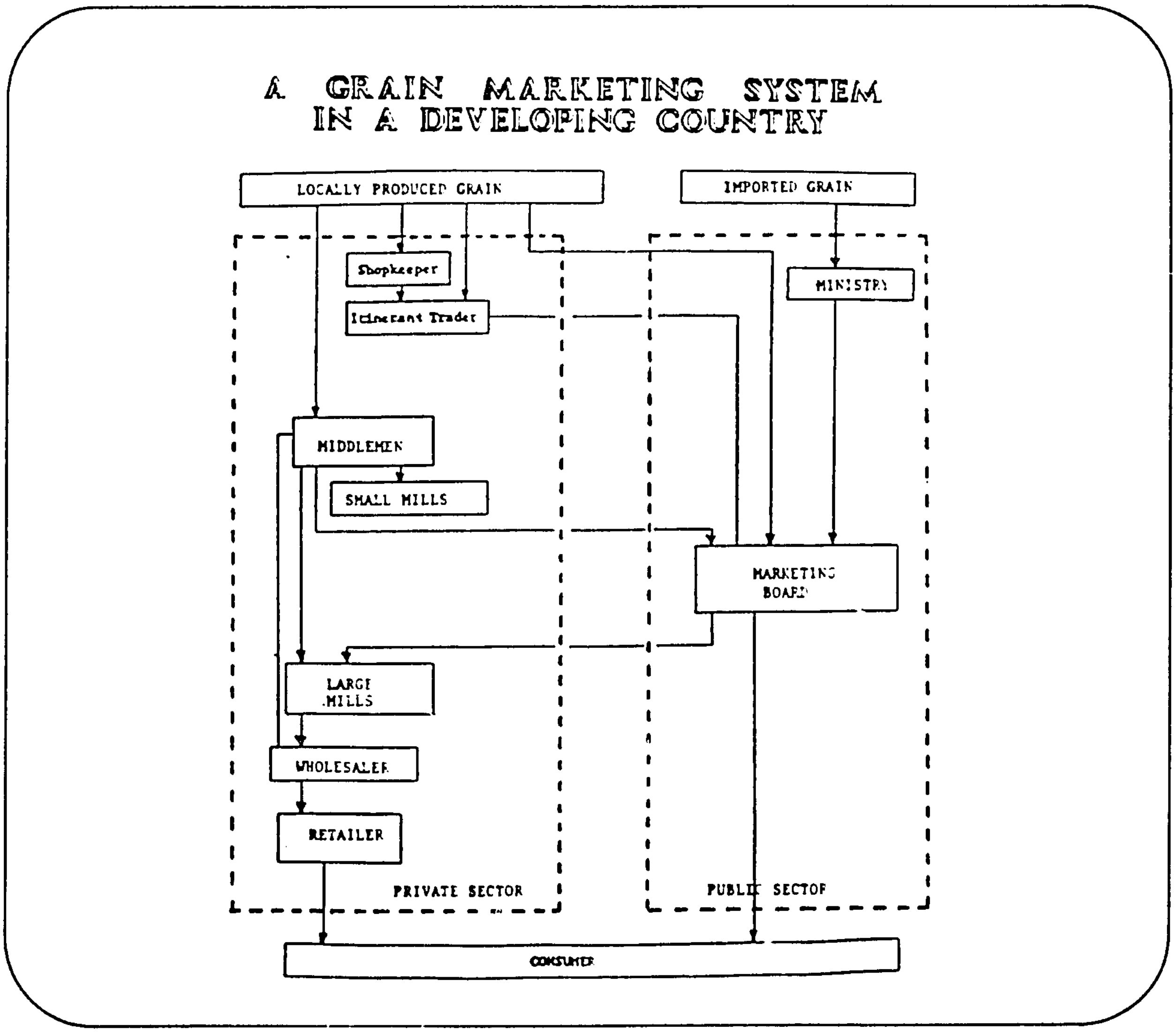


Figure 11.2. A government controlled grain marketing system in many developing countries.

the government buys and timing of their buying and selling activities.

In Pakistan, government intervenes in the wheat market by (1) establishing procurement and release prices, (2) acquiring up to 70 percent of the market supply, and (3) storing, transporting, and distributing wheat. Pakistan wheat policies are distinguished by two unique features - uniform procurement and release prices, and pan-territorial or nationwide uniform prices. Costs of storage and distribution are subsidized by the federal and provincial governments. These policies have discouraged investments in grain storage and distribution by the private section. Until the late 1980s, the government procurement and release prices were identical with the government absorbing all market costs.

Various Pakistan governments have tried to organize farmers cooperatives to enable producers to perform the marketing functions themselves. The farmers cooperatives provided production loans and services to their members. Many were patterned after western models complete with financial support and governmental backing. However, cooperatives have been ineffective mainly because of a lack of clear definition of their objectives. Dishonesty and lack of managerial skills and discipline among its officers and members was another stumbling block to achieving success. On the other hand, cooperatives have succeeded in Taiwan, Korea, and Thailand to name a few countries. Many of these cooperatives have become models for other countries to follow. It is not surprising that these countries are now among the most progressive countries in the region.

C. Law of Supply and Demand

The law of supply and demand determines the movement of grain from production to consumption. The grain flows from production to consumption as long as there is a demand for it. This demand creates various functions and services from production to consumption. The private section usually performs these functions and services in a free market system.

The price of grain is usually low when there is an oversupply at harvest or when there is a bumper crop. Producers usually store surplus grains and sell when the price goes up during the lean months. The availability of food and feed grains follow a cyclic pattern in most developing countries. The price of grains rises when there is scarcity and decreases during the harvest months. The governments in developing countries usually intervenes to keep the price within a predetermined price band to protect the public. To intervene, the government has to buy enough stocks to be able to influence the price of the commodity.

The intervention requires large capital outlays to build food reserves. It further requires an efficient organization and infrastructure to store and distribute the grain to the public. A grain marketing board usually carry out these functions. However, most grain marketing boards have limited budgets and infrastructure. Most have inadequate management and operational expertise. An yet they assume the leading role in collecting and distributing the grain. It controls the price of grains to encourage production but more often stifles the grain trade with its pricing policy and outdated rules or regulations. Such rules restrict the movement of wheat between districts even within the same province. In Pakistan, a rule called Section 144 carries a state of emergency measures the government invokes to meet its procurement goals.

Most government food agencies have large organizational setups with inadequately trained and poorly paid personnel. The often serve as employment agencies for political lords. Many have ambitious plans to solve postharvest problems but are difficult to carry out for want of funds. Some contrive temporary solutions to chronic problems in grain storage and marketing instead of formulating permanent long-term solutions. Their response to new ideas is usually favorable but never really the courage to adopt new technologies. If they ever do, they move very cautiously because of past bad experience and because of bureaucratic red tapes and forces of inenia.

In contrast, the private sector in developed countries perform the same functions in more efficient manner. They normally have access to good financing either for operating capital or investment for new facilities. They also have the technical know-how and the support of the government to solve their technical problems through the state universities and research institutions. Furthermore, stiff competition existing among themselves promotes efficiency and also forces the private industry to provide better services to their customers at competitive costs.

REVIEW QUESTIONS

1. *Give the differences between a government controlled grain marketing system and a system controlled by the private sector.*

2. *What are the four primary utilities in marketing?*

3. *Explain the law of supply and demand.*

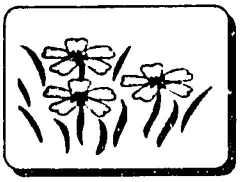
4. *What are the advantages of having competition in marketing?*

5. *What are the effects of fixed pricing system in grain marketing on the private sector? The public in general?*

6. *What is the meaning of FAQ? How did originate in Pakistan?*

7. *Should the government always get involved in grain marketing? Why?*

GLOSSARY



Absorption: The transfer or movement of liquid water into the structure of grains.

Aeration: The moving of air through stored grain at low airflow rates to maintain its quality.

Adsorption: The transfer of water vapor from the surrounding into the grain. The opposite of desorption.

Aflatoxin: The mycotoxin produced by the mold or fungi *Aspergillus Flavus.*

Airflow: The volume of air moved per unit time. Usually in cubic feet per minute or cubic meter per minute.

Angle of Repose: The natural angle or slope formed by the surface of a pile of grain to the horizontal plane.

Aspiration: A process of cleaning grain by sucking away light particles from a stream of grain using a fan.

Avicide: A chemical that poisons birds.

Bag Storage: A storage structure suitable for storing grains and other commodities in bags.

Biomass: Agricultural waste products like wood, straw, husks, and nut shells that have heating or energy value.

Blower or Fan. A device used to move large volumes of air by force or pressure.

Bran: The outer covering of cereal grains after removing the husk.

Brokens: Pieces of the grain kernel that are less than 3/4 the full size kernel.

Bulk Storage: Storing of grains in loose form without using bags.

Btu (British thermal unit): Energy equivalent to the amount of heat that will change the temperature of one pound of water one degree Fahrenheit. 1 Btu = 252 calories.

Calorie: Energy equivalent to the amount of heat that will change the temperature of one gram of water one degree centigrade.

Cleaning: The process of removing foreign materials and impurities from grains.

Combine: A self-propelled machine that cuts, threshes, cleans, collects, and then transports grain crop in one operation.

Conveyor: A mechanical device that moves grains from one place to another.

Country Elevator: A storage facility that a cooperative society uses for storing grains. .

Cyclone Separator: A funnel-shaped device that separates solid particles from an air stream.

De-stoner: A machine that separates grain from stones or small rocks.

Desorption: The transfer of water vapor from the grain to the atmosphere. It is a drying process.

Discolored Grains: Grains that have changed to a yellowish, brownish or black color because of heating in storage.

Dockage: A classification of any foreign materials contained in a grain sample. A grain standard describes a procedure of removing dockage from grain samples.

Drying: The process of removing excess moisture in grains by natural or artificial means.

Dunnage: Wooden frame that supports a stack of bags. Its main function is to prevent moisture absorption from the floor to the bags.

Dust: A powdery form of inert material in a grain mass. Sieves and aspirators remove dust during cleaning operation.

Equilibrium Moisture Content: The moisture content that grains reach after exposure to a constant environment for an infinite time.

Flat Storage: A grain storage structure whose height is less than its width or diameter. A warehouse or godown is a flat storage.

Foreign Matter: Other matters such as stones, sand, or other seeds, remaining in the grain after the removal of dockage.

Fumigant: A pesticide which may be in solid, liquid or gas form that moves in gas form and kills insects and animals alike.

Fan: A device with rotating blades that forces the movement of air. It is synonymous with a blower.

Fumigation: The process of controlling pests with the use of a fumigant.

Fungicide: A chemical that controls molds or fungi.

Godown: Another term for a warehouse.

Grading: The testing of a grain quality by separating defects and impurities from the sound grains.

Grain Grade: A grain quality designation that satisfies a specification in a grain standard.

Grain Standard: A document that describes grain grades and detailed procedure of determining grain grades.

Grain Terminal: A large grain storage installation that a private or government food agency uses to store grains for domestic or foreign markets.

Harvesting: The process of cutting the grain heads from the mother plant.

Head Yield: The amount of unbroken white rice obtained from milling paddy rice. It is the total milled rice minus the broken rice.

Hull or Husk: Outer covering of cereal grains.

Hygroscopic: The characteristics of a material to gain or lose moisture to the surrounding air. All agricultural products are hygroscopic.

Indented Cylinder: A rotating cylindrical device with internal indentations or pockets that separates grains of two different lengths.

Indented Disc: A device consisting of discs with indentations or pockets that separates grains of two different lengths.

Larva: A stage in the life cycle of insects with complete metamorphosis. It is the stage after the egg.

Moisture Content: The amount of water in the grain.

Moisture Meter: An electronic device that measures the amount for water in grains indirectly using its electrical property.

Mold or Fungus: Lower form of plant that attacks either plants and animals.

Mycotoxin: A toxic substance that molds produce while growing in a product such as cereal grains.

Paddy: The complete rice kernel with the husk on it. It is synonymous with rough rice.

Pesticide: A chemical that controls pests like insects, birds, and rodents.

Postharvest Losses: All loses that occur after harvesting a crop until it reaches the consumer.

Post Production: The stage or period after the crop reaches maturity.

Quality: A condition of a grain sample which is a basis for its acceptance or rejection by a buyer.

Random Sampling: The taking of grain sample with each grain having equal chance of being drawn.

Reaper: A machine that only cuts or harvests the heads of grain plants and lays it in rows in the field.

Relative Humidity: The ratio of the actual moisture in the air to the amount of moisture that air can hold at saturated condition.

Sample Divider: A device that divides a grain sample into two equal parts.

Screen/Sieve: A device made of wire mesh or perforated sheet metal that grain graders uses to separate grains from other materials.

Screening or Sieving: The process of separating different size particles by using a wire mesh or perforated sheet metal.

Silo: A cylindrical structure made of concrete or metal that stores bulk grains.

Sorption: A general term which refers to the transfer of water vapor to and from the grain (see desorption and adsorption).

Test Weight: The weight of a bulk grain per unit volume either in pounds or kilogram. Example: Pounds per bushel or kilogram per hectoliter.

Threshing: The process of detaching the grain kernels from the panicle manually or with a machine.

Total Milling Yield: Percentage of total milled rice from paddy which includes head rice and broken rice.

Trier: Small metal probe grain graders use for taking samples of grain from bags or from bulk containers.

Viability: The germination potential of a seed grain expressed in percent.

Warehouse: Building suitable for storing grains and other commodities either in bulk or bag form.

Windrow: Harvested plants lying in rows in the field.

Windrower: A machine that arranges harvested plants into windrows.

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ANNEXES

A. MOISTURE CONTENT DETERMIATION

B. CALIBRATION OF MOISTURE METERS

C. PHOSPINE FUMIGATION IN HEXAGONAL BINS

D. PHOSPHINE FUMIGATION IN OPEN BULKHEAD

E . IMPORTANCE OF GRADING

MOISTURE CONTENT DETERMINATION

The determination of the moisture content of agricultural products is broadly classified into (1) direct and (2) indirect methods. The amount of moisture measured in the direct method relates to the amount of dry matter present or to the original weight of the product. Thus, one finds moisture expressed either on the basis of the dry matter content (dry basis) or on the basis of its original wet weight (wet basis). While the direct methods may not be any more accurate than the indirect methods, they are usually accepted as standards for the calibration of indirect methods of moisture measurements.

Regardless of the method one uses in determining the moisture content of a product, there are possibilities of errors in the measurement process. The major error can occur in the improper use of the moisture meter or equipment. Another source of error is in the problem of securing a sample that is representative of the entire lot of product. It is therefore important to follow the accepted procedures in gathering representative samples and the recommended use of moisture meters or testers.

A. Direct Methods:

There are several methods of measuring directly the amount of moisture present in a product, such as cereal grains. These methods remove the unbound moisture from the product.

1. Oven methods.

The procedure removes the moisture in the product by heating. A sample placed in an air-oven or water-oven losses its moisture after a specified length of time. One procedure requires grinding of a grain sample with moisture below 13% before placing it in the oven. Another procedure requires a two-stage method of determination with grains having moisture above 13%. This method uses whole grain sample for the first stage until its moisture reaches about 13% and then uses the first procedure for the second stage.

a. Air-oven method, $130^{\circ}C \pm 1^{\circ}$ ($266^{\circ}F$)

(1) One-stage, for grain under 13% moisture. Grind duplicate samples of 2 to 3 grams each. Heat 1 hr at $130^{\circ}C$ ($266^{\circ}F$). Place in desiccator; then weigh. The samples should check within 0.1% moisture.

(2) Two-stage, for grain above 13% moisture. Remove moisture until 25 to 30 gram sample is below 13% (usually about 14 to 16 hr in oven). Continue as in procedure (1) above.

b. Water-oven or Air-oven method, $100^{\circ}C$ ($212^{\circ}F$)

Place duplicate 25 to 30 gram samples in oven, heated to 99 to $100^{\circ}C$ (211-$212^{\circ}F$) for 72 to 96 hr. Place in dessicator, then weigh. Samples should check within 0.1% moisture.

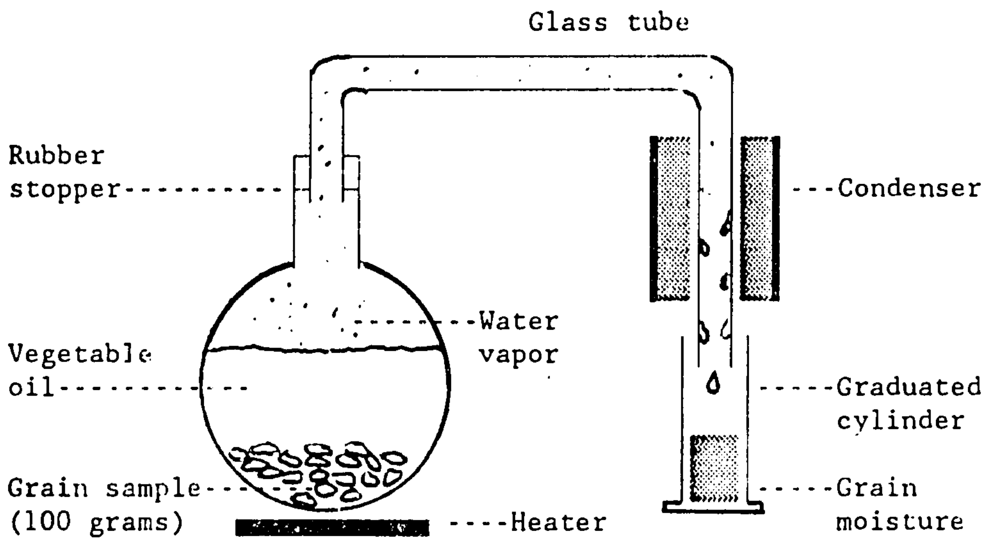
An alternative method is to leave the sample in the oven until its weight loss stops. However, it is impossible to remove all the moisture in the grain without causing deterioration of the dry matter in the product. Experience indicate that 96 hr is about the maximum allowable time for most grains in the oven without causing dry matter loss.

c. Vacuum-oven method

This method requires the grinding of the grain sample before placing it in a vacuum oven set at 100°C (212°F). The process requires 5 hours in a negative pressure of 25 mm Hg (0.48 psi). This method minimizes grain degradation because of the shorter duration and lower temperature used.

d. Distillation method

The most common distillation method is boiling a 100 gram sample in vegetable oil for about 15 minutes. The volume of the condensed moisture collected in a graduated cylinder is the weight loss of the sample. As an example, a 15 c.c. moisture collected from a 100 gram sample means 15% moisture content.



Schematic diagram of a distillation-type moisture meter

e. Desiccation method

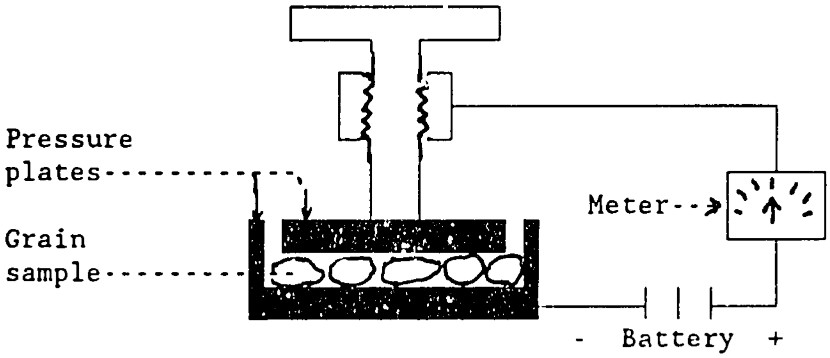
A desiccant, such as salt, dries a sample in a closed container. The method requires finely ground sample to obtain faster response. However, molds may develop in high moisture samples before ever completing the process. It has practical application for low moisture grain samples.

B. Indirect Methods

Indirect methods of moisture determination involve the measurement of a property of the product, such as electrical or thermal property, that relates to moisture content. The amount of moisture is in wet basis and manufacturers calibrate the meter against a direct method of moisture determination. There are various indirect methods of moisture determination. However, only three methods is of any practical use in the Grain Industry.

1. **Electrical resistance methods.**

This type of a moisture meter uses the electrical resistance or conductivity of a material to determine indirectly its moisture content. The principle of operation involves two plates (electrodes) that measures the electrical resistance of the grain placed between them (see Figure below).



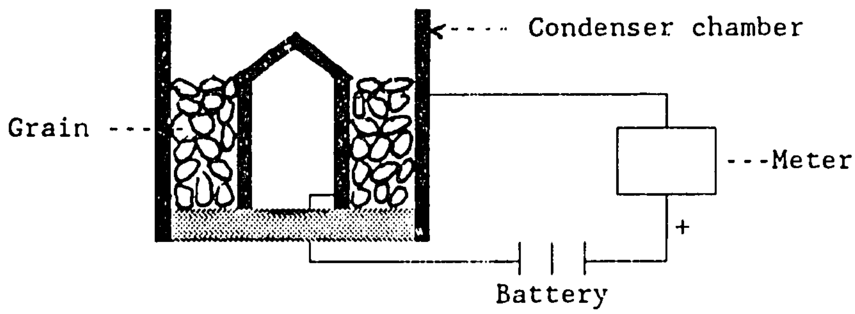
Schematic diagram of a resistance-type moisture meter.

The electrical resistance of a product is inversely proportional to its moisture content. This is because moisture helps in conducting eletricity through a product. This type of a moisture meter still needs calibration for each grain against a direct method of moisture measurment. Aside from moisture, the electrical resistance of a material is also affected by temperature. Therefore, one needs a correction factor to compensate for deviation from the temperature at which calibration was based. Aside from temperature and moisture content, the electrical resistance is also affected by the pressure imposed on the grain sample. The electrical resistance of grain decreases with an increase in pressure. Hence, a consistent pressure imposed on the grain is critical in the accurate operation of the meter.

Most electrical moisture meters do not give readings below 7% because of negligible change in electrical conductivity at very low moisture levels. Also, electrical resistance moisture meters give lower moisture readings for grain that has recently been dried. This is because of their tendency to measure the electrical resistance on the grain surface. Conversely, they give higher moisture readings for re-wetted grain such as the case in the conditioning of wheat prior to milling.

2. Dielectric methods (capacitance)

This type of a moisture meter uses the dielectric properties of a product. Moisture meters of this type have a cell or chamber that serves as a condenser. The capacity of this condenser is affected by the dielectric properties of the grain in the cell. Grains with high moisture contents have higher dielectric constant than dry grains. Water has a dielectric constant of 80 at 20°C (68°F), air in a vacuum has a value of 1, and most grains have a value less than 5. Capacitance type moisture meters measure this property and relates it to the grain moisture content. Capacitance-type meters are less subject than resistance meter to any errors due to uneven moisture distribution after grain drying or re-wetting. However, readings are affected by temperature and compaction of the product. Hence, they also have temperature corrections factors and most have a system of loading sample to have uniform distribution in the condenser.



Schematic diagram of a capacitance-type moisture meter.

3. Hygrometric method

This method measures the relative humidity of the air in equilibrium with an enclosed grain, thus, its moisture content is determined indirectly. Some hygrometers have sensing tips that one can insert into a grain mass to measure the relative humidity of the interseed air. Hygrometric type of moisture meters have useful application in monitoring remotely moisture content of bulk grain.

4. Other methods

There are other methods of determing the moisture content of a product, such as (1) newtron scattering method and (2) nuclear resonance-absorption method. However, they are still impractical and uneconomical to use at this stage.

Because of the importance of moisture determination in grain trade, several grain exporting and importing countries have developed their own Approved Methods of moisture determination. Table 1 below gives examples of of approved methods of moisture determination in some countries for barley, corn, and wheat. Meanwhile, Table 2 gives the oven temperature used by the U.S. Federal Grain Inspection Service in determining the moisture of oilseeds and cereal grains.

TABLE 1.
Examples of Approved Methods of Determining Moisture Contents of Some Cereal Grains

Group[a] or Country	Grain		
	Barley	Corn	Wheat
USDA	Air method[b] 5 Motomco meter[c]	Air method 2 Motomco meter	Air method 5 Motomco meter
AACC	Air method 5 Vacuum method[d] 1 Motomco meter	Air method 2 Motomco meter	Air method 5 Motomco meter
AOAC	Air method 5 Vacuum method 1	...	Air method 5 Vacuum method 1
Canada	Air method 5 Motomco meter	Air method 2 Motomco meter	Air method 5 Motomco meter
England	Air methods 1, 5, and 6		Air method 5 Motomco meter
France	Air method 6 Glass tube drying[e]	Air method 7	Air method 6 Glass tube drying
ICC	Air method 6 Glass tube drying	Air method 2	Air method 6 Glass tube drying
USSR	Air methods 3, 4, and 9 Vacuum method 2	Air methods 3, 4, and 9 Vacuum method 2	Air methods 3, 4, and 9 Vacuum method 2

[a] USDA = U.S. Department of Agriculture; AACC = American Association of Cereal Chemists, AOAC = Association of Official Analytical Chemists, ICC = International Association for Cereal Chemistry.
[b] Air oven methods: 1 = 103°C, 4 hr; 2 = 103°C, 72 hr; 3 = 105°C, 30 min, plus 130°C, 40 min; 4 = 130°C, 40 min; 5 = 130°C, 1 hr; 6 = 130°C, 2 hr; 7 = 130°C, 38 hr.
[c] Model 919.
[d] Vacuum oven methods: 1 = 98–100°C, 5 hr or constant weight; 2 = 105°C, 30–40 min, plus 130°C, 1 hr.
[e] At 10–20 mm of Hg, 45–50°C, with P_2O_5.

TABLE 2.
Oven Methods of the U.S. Department of Agriculture, Federal Grain Inspection Service

Seed	Temperature (°C)	Time (hr)	Sample Weight (g)
Oil seeds			
Flax	103	4	5–7
Safflower	130	1	10
Soybeans	130	1	2–3
Sunflower	130	3	10
Starchy seeds			
Barley[a], Oats[a], Rice[b], Wheat[a]	130	1	2–3
Corn[c]	103	72	15

[a] If moisture content is over 16%, use two-stage procedure.
[b] If moisture content is over 13%, use two-stage procedure.
[c] If moisture content is over 25%, use 100-g sample.

CALIBRATION OF MOISTURE METERS FOR ROUGH RICE USING THE OVEN STANDARD METHOD

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EXECUTIVE SUMMARY

In Pakistan, the most commonly cultivated varieties of rice are IRRI-6, KS-282, Basmati-Pak, and Basmati-385. The procurement of paddy is based upon some qualitative factors along with the moisture content of the grain. The moisture content is determined with the use of different moisture meters by various rice procuring agencies. However, these meters are never calibrated against the reference oven method. In the present study, nine available moisture meters were calibrated against reference oven method for the four above stated varieties of paddy. Regression equations for different moisture meters for each variety along with its correlation coefficient were determined to evaluate the reliability of the results. Conversion charts are also given for the benefit of ultimate users of the moisture meters during paddy procurement, drying, storage, and milling. The accuracy of each moisture meter for different varieties at various moisture ranges is also discussed. It is noted that most of the moisture meters studied gave readings close to the reference oven method at lower limits of moisture content, while they differ with that of oven values at higher moisture content ranges.

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INTRODUCTION

Importance of Grain Moisture

Cereal grains are hygroscopic in nature and thus gain (adsorb) or lose (desorb) moisture depending on the surrounding environmental conditions. The speed of this process is influenced by the vapor pressures of the air and the grain. At a given temperature and relative humidity, grains have a corresponding moisture content which form sigmoid or equilibrium moisture curves. The moisture content of cereal grains play an important role in grain storage. At higher relative humidity levels, the chance of insect and mold growth in stored grain is greater than at lower relative humidity levels. Excessive multiplication of insects and rapid growth of molds and bacteria can further cause a considerable increase in moisture content (Christensen and Kaufmann, 1969). Insect infested grain will have nutritive depletion and receive a discounted price at the market.

During procurement and selling operations, the moisture content of grain influences its weight as well as its price. Grain with a high moisture content has less dry matter which contains the food value. Paddy is harvested at 20-22% and milled at 12-14% moisture content. At the time of procurement, about 7-8% excess moisture is present at which traders determine their margin of profit. Therefore, the exact knowledge of moisture content at the time of purchase, storage, and milling is extremely necessary to avoid economic losses.

Determination of Moisture Content

Moisture content of agricultural products can be determined by either direct or indirect methods. Common procedures under each method include the following:

1. Direct Methods

   (a) Oven Method

   In this method, the commodity is dried at a certain temperature for a known period to remove the water by evaporation. The difference in initial weight and the bone-dry weight of a product represents its moisture content. The International Standards Organization (ISO) recommends the drying of a ground sample of cereal grain for two hours at 130 ± 3°C (ISO, 1979). The oven method is considered to be the most accurate method but does have drawbacks. The method is time consuming and not rapidly repeatable. It is normally used as a reference method for the calibration or evaluation of other moisture determination methods.

   (b) Chemical Method

   In this method, free moisture in the ground material is extracted by a reagent. Such a method is to be calibrated against a reference method of drying up to a constant weight under reduced pressure.

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(c) Distillation Method

In the distillation method, moisture is removed by heating the grain in oil and determining the volume or the weight of the water removed from the grain in condensed vapor or from the loss of weight of the sample (Hall, 1980).

2. Indirect Methods

(a) Electrical Method

In the electrical method, moisture content is measured by specially designed moisture meters. Light weight, portability, and repeatability are the major advantages of these meters which favor their worldwide use. The moisture meters are of two types which measure the electrical properties of grains.

(1) Capacitance Type

This type of meter uses the capacitance or dielectric properties of the grain. Moisture meters of this type have a cell or chamber that serves as a condenser. Grains with high moisture content have higher dielectric constants than the dry grains.

(2) Resistance Type

This type of meter uses the electrical resistance or conductivity of the grain. The electrical resistance of a product is inversely proportional to its moisture content.

The electrical method does not give results consistent to those given by the oven method. In resistant type meters, a small decrease in moisture content may produce a large increase in resistance and vice versa. This is why most resistance type meters are accurate at middle-moisture ranges.

Apart from the moisture content, the resistance or dielectric (capacitance) properties of grains are affected by their physical and chemical composition, kernel size, shape, and temperature. The relationship between the electrical properties and moisture content varies considerably with type, variety, and condition of the commodity (Mackay, 1967). It is therefore essential that the relationship between the electrical reading of a meter for a given variety of grain should be calibrated against a reference method.

Different varieties of the same commodity have different electrical properties. It is therefore necessary to calibrate moisture meters to make them useful.

Background and Objectives

In Pakistan, paddy is purchased from the farmers on varietal basis. The Rice Export Corporation of Pakistan (RECP) and Pakistan Agricultural Storage and Services Corporation (PASSCO) are the major public-sector procurement agencies.

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PASSCO may either resell the paddy or milled rice to RECP or to the private sector. In the private sector, most rice mills purchase the paddy directly from the farmers. Paddy procured by RECP and the private sector is processed and the milled rice is exported. The procurement price is based on the variety and the moisture level of the produce. For moisture determination, RECP, PASSCO, and a few large-size rice mills, normally use electrical moisture meters. Most rice mills do not use moisture meters at all. Their buying prices are based on cursory visual inspection of the paddy. This includes biting, rattling, feeling, and other observation methods. It was observed by the Pakistan Agricultural Research Council/Storage Technology Development and Transfer (PARC/STDT) project personnel, in their informal surveys, that no meter is calibrated against the Standard Oven Method to obtain accurate moisture measurements. The accurate determination of grain moisture is very important for both the seller and the buyer. A seller can get the true value of the grain while a buyer can accurately dry, mill, and store the grain with knowledge of its moisture level.

Calibration of moisture meters for different varieties of wheat was done by DeLima and Salihah (1984) and Mahmood et al. (1989). DeLima and Salihah calibrated four moisture meters (two capacitance and two resistance type) for only two varieties of paddy (Basmati-370 and IRRI-6). With the introduction of new rice varieties and different moisture meters, the need to calibrate the moisture meters led to the conduct of this study for the benefit of public and private rice traders.

The objectives of the present study are:

1. To calibrate available electrical moisture meters with the Standard Oven Method by using most commonly cultivated Pakistani rough rice varieties.

2. To develop regression equations and conversion tables for each paddy variety for the available moisture meters.

3. To determine the most appropriate moisture meter to be used for prevalent rough rice varieties at a given moisture range.

Table 1. Moisture meters used in the study and their characteristics.

No.	Name of Meter	Model	Manufacturer	Type	Moisture Range	Weight	Sample Wt.	Size (cm)	Power Supply
1	Burrows Digital Moisture Computer	700	Burrows Equipment Co., Illinois, USA	Capacitance	1 - 100 %	7.8 Kg.	250 gm	31.1 x 15.6 x 42.6	AC mains or 12 volt battery
2	Dole Digital Grain Moisture Tester	500	Seedburo International Equipment Co., Chicago, USA	Capacitance	7 - 40 %	0.45 Kg.	60 gm	14.9 x 7.9 x 5.1	9 volt transistor battery
3	Dickey-john Grain Moisture Tester	DJGMT	Dickey-john Co., Illinois, USA	Capacitance	10 - 40 %	1.3 Kg.	200 gm	25.4 x 12.0 x 19.0	9 volt transistor battery
4	Motomco Moisture Tester	919	Motomco Inc., Paterson, New Jersy, USA	Capacitance	1 - 100 %	6.8 Kg.	200 gm	24.1 x 24.1 x 21.6	AC mains or 55.5 volt battery
5	Insto Farm Grain Moisture Tester	Insto 1	Insto Inc., Auburn, Illinois, USA	Capacitance	10 - 40 %	1.2 Kg.	200 gm	24.1 x 11.7 x 17.8	9 volt transistor battery
6	Datatec Moisture Analyzer	P - 25	Sinar Technology Unit, Surrey, UK	Capacitance	1 - 100 %	2.4 Kg.	200 gm	31.2 x 16.8 x 12.5	6 volt transistor battery
7	Kett Digital Grain Moisture Tester	Riceter-L	Kett. Electric Co., Tokyo, Japan	Resistance	10 - 30 %	0.64 Kg.	0.50 gm	15.8 x 8.9 x 4.0	6 volt transistor battery
8	Delmhorst Crop Moisture Detector	G - 6C	Delmhorst Instrument Co., Towaco, New Jersy, USA	Resistance	9 - 30 %	1.7 Kg.	3.00 gm	17.4 x 15.1 x 8.1	9 volt transistor battery
9	Shizuoka Comet Run Moisture Meter	CR - 1	Shizuoka Seiki Co., Japan	Resistance	11 - 36 %	0.62 Kg.	0.50 gm	18.0 x 9.7 x 3.2	6 volt transistor battery

MATERIALS AND METHODS

Moisture Meters

The following moisture meters were evaluated for their accuracy and calibrated with the Oven Standard Method:

1. Burrows-700 digital moisture computer
2. Dole-500 digital grain moisture tester
3. Dickey-john grain moisture tester
4. Motomco-919 moisture tester
5. Insto-1 farm grain moisture tester
6. Sinar Datatec P-25 moisture analyzer
7. Kett Riceter-L digital grain moisture tester
8. Delmhorst G-6C crop moisture detector
9. Shizuoka Comet Run CR-1 moisture meter

The salient characteristics of these moisture meters are described in Table 1.

Rice Varieties

The following rough rice varieties were used for calibration of the above mentioned moisture meters. These varieties were obtained from the Rice Research Station, Kala Shah Kaku.

1. IRRI-6
2. KS-282
3. Basmati-385
4. Basmati-Pak (Kernel)

Conditioning of the Grains

About 4.5 kg of cleaned fresh grain from each variety was obtained and its initial moisture content on the wet basis was determined by the air oven method. For this purpose, 1.5 cm thick layers of each sample were placed in trays and put in the air oven at 45°C. The grains were weighed before and after heating and the moisture content was calculated by using the following formula:

$$b = 100 - \frac{A\,(100 - a)}{B}$$

where

- b = Final moisture content of the sample
- a = Initial moisture content of the sample
- A = Initial weight of the sample
- B = Final weight of the sample after drying

By using this method, all varieties were dried to 11% moisture content. Each sample was then divided by a riffle divider to get a sub-sample of 250 gm. These sub-samples were weighed to within ± 0.1 g accuracy and placed in glass jars of 1 liter capacity. They were then adjusted to a range of 11-24% moisture content. This was done by adding measured quantity of distilled water along the inner walls of the jars with a pipette (Gough, 1975). All the samples were therefore used for calibration of the adsorption process. The desired amount of water added to each jar to get appropriate moisture content was calculated by using the equation stated by Pixton (1967).

$$\text{Amount of water to be added (ml)} = \frac{W_1 (M_1 - M_2)}{100 - M_2}$$

where

W_1 = Initial weight of grain (gm)
M_1 = Initial moisture content (%)
M_2 = Final moisture content (%)

The jars were closed air tight with lids and sealed with PVC self-adhesive tape. The samples having a moisture content of 14% or lower were kept at room temperature while those having a higher moisture content were placed in the refrigerator at $5^{o}C$ to prevent mold growth (Gough, 1983; Pixton and Warburton, 1973). The jars were shaken continuously for the first three hours and then two-three times daily for five weeks to ensure even distribution of the moisture in the grains.

Use of Moisture Meters

After five weeks, the jars of various varieties were opened and the moisture content of the grains was measured with the nine given moisture meters. All moisture meters were used in accordance with manufacturer's instructions. All necessary precautions and temperature corrections were made where necessary. Three replicate readings were taken with each meter.

Reference Oven Method

A Lab-Line's L-C oven was used for moisture content determination of the grains. The oven temperature and time was in accordance with the ISO method R-172 and the International Seed Testing Association Standards, i.e. 130 ± $3^{o}C$ for two hours for rough rice.

Standard aluminum tins of 5.6 cm diameter and 1.5 cm deep were cleaned, oven dried, and cooled in desiccators before use. Approximately 25 gm of grain was taken from each test jar after thoroughly mixing and grinding in a Kenwood grinder using 30-mesh wire screen through which about 15% of the ground sample is passed (Oxley et al., 1960). About 5-6 gm of the ground sample was transferred to pre-weighed and labelled aluminum tins using a scoop. The tins were weighed again by a Fisher electronic balance to 0.1 mg accuracy. The tins were then placed in a pre-heated oven with no lids. After two hours, the tins were covered with lids and then removed from the oven and cooled inside desiccators for 45 minutes. After cooling, each container was weighed again. Three replicates were made for each determination.

The percent moisture content was calculated by using the following formula:

$$\% \text{ m.c (wb)} = \frac{(A - B)}{A} \times 100$$

where

A = Initial weight (gm)
B = Final weight (gm)

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RESULTS AND DISCUSSION

Tables 2-5 show the regression equations, correlation coefficients, coefficient of determination, and standard error of slope for the different moisture meters against the Oven Standard Method for each variety. The equations express the regression of the Oven Standard Method (Y) on moisture meter readings (X). By using these equations, the value of the Oven Standard Method can be predicted by putting the moisture meter values. The correlation coefficient indicates the strength of the relationship between the two types of observations. On the other hand, the coefficient of determination ascertain the percentage of variation accounted for by one variable in determining the other variable.

Relationship Between Oven Method and Moisture Meter Values

It is apparent from Tables 2-5 that the degree of relationship or correlation coefficient (r) between moisture meter readings and the oven standard values were highly significant ($p < 0.001$) for all varieties. Very high correlations (99.9% and 99.7%) were found for the Dickey-john moisture meter for IRRI-6 and KS-282, respectively. Kett Riceter-L, Burrows digital, and Shizuoka Comet Run moisture meters also showed a high level of accuracy in prediction (98.3% to 99.8 %) for all varieties. All other moisture meters also showed a high degree of accuracy levels (>95.0%) for all experimental varieties.

Tables 7 to 42 show the actual conversion values for all moisture meters against Oven Standard Method for each variety. These values are calculated by using the regression equations given in Tables 2-5 for the convenience of the ultimate users of moisture meters.

Accuracy of Moisture Meters

The accuracy is a desirable static characteristics of an instrument which does not vary with time. This is expressed within ± x percent of the instrument span at all points on the scale, unless otherwise stated (Eckman, 1966). The accuracy of various moisture meters deviate significantly with different varieties and moisture ranges. The accuracy of the moisture meters studied was tested within 0.55% to the Oven Standard Method. Details pertaining to accuracy of different moisture meters at different moisture ranges for all varieties are summarized in Table 6. Some details in this context for each moisture meter are given below:

1. Burrows digital moisture computer

   The accuracy of the Burrows meter is within 0.55% for all varieties tested at lower ranges of moisture content (11.8-15%). This moisture meter is reliable for rough rice at low moisture levels with least errors without using a conversion chart. The Burrows moisture computer can be adjusted for any variety by using the slope and intercept of the regression equation. This moisture meter is bulkier than other moisture meters and is more suitable in the laboratory than in the field.

2. Dole digital moisture tester

This is a small hand-held moisture meter very suitable for field work. It is accurate within a moisture range of 12.2 to 16.0%. The difference between meter and oven values is 0.02-0.54% for all varieties at the above range.

3. Dickey-john moisture tester

This is also hand-held meter but much larger than the Dole moisture meter. This meter is commonly used for determining the moisture content of wheat and corn. It can be used for paddy as well. The meter is found accurate at lower ranges (9.7-14.4%) of moisture content for all varieties. The difference between the meter and oven values is 0.00 to 0.53%. The correlation coefficient for this meter is also very high for all varieties. Therefore, this meter has a very high degree of accuracy at given ranges for all the rough rice varieties used. For higher ranges however, it requires the use of a conversion chart.

4. Motomco moisture meter

This is a portable but relatively heavy moisture meter and should only be used in the laboratory. It requires temperature correction after reading the moisture values. The accuracy of this meter is maximum at lower ranges (12.2-14.0%) of moisture content with a difference of 0.08 to 0.64% for all four varieties. Although the correlation coefficient for this meter is highly significant (96.7% to 98.5%), the difference between the two values (meter and oven value) increases consistently for higher ranges of moisture content.

5. Insto moisture tester

This is a capacitance-type moisture meter but its accuracy range is comparatively higher than the other capacitance type moisture meters used in this study. This meter is highly accurate at 13.0 to 16.4% moisture content, with a difference of 0.03 to 0.55% for Basmati-Pak and Basmati-385. For KS-282, it is accurate at relatively higher moisture ranges (14.0-18.0%) than other varieties with a difference of 0.5% moisture content. For IRRI-6, it does not show any accuracy at any range. The difference between two values (oven and meter reading) is very high at all moisture ranges.

6. Datatec moisture analyzer

This meter is slightly larger than the Dickey-john meter and can be used in the laboratory and in the field. The maximum accuracy of this moisture meter is at very low ranges of moisture content (8.0-10.0%) for IRRI-6 and KS-282 varieties. The range is relatively higher (8.0-11.2%) for Basmati-Pak and Basmati-385 with a difference of 0.01 to 0.6% for various varieties.

7. Kett Riceter-L moisture tester

This is a hand-held resistance type moisture meter and can be used for determining the moisture content of various cereal grains. The accuracy range of this moisture meter differs with different varieties. For Basmati-Pak, the best accuracy of the meter is at 8.0 to 16.0% moisture content with a difference of 0.48 to 0.6%. It is accurate in a wide range of moisture contents (8.0-34.8%) for IRRI-6 with a difference of 0.66% between the two values (oven and meter). On the other hand, the accuracy of the meter stays at higher levels of moisture values (29.8-34.8%) for KS-282 while, for Basmati-385, it does not show any range of moisture content which is closer to that of oven values.

8. Delmhorst crop moisture detector

This is a portable resistance type moisture detector and can determine the moisture content of various grains. The accuracy of the meter is higher at 10.8 to 21.0% and 10.6 to 22.0% for IRRI-6 and Basmati-385, respectively, with a difference of 0.0-0.5%. This range is lower (12.2-14.4%) for KS-282. For Basmati-Pak, the accuracy was noted within 0.5% at a moisture range of 8.0-17.0%.

9. Shizuoka Comet Run moisture detector

It is a hand-held resistance type moisture detector. Although the strength of relationship between the meter's readings and oven values is highly significant 97.6 to 99.2% at 99% confidence limit, the meter consistently over-estimated the moisture content by 1-3% for different varieties. It shows accuracy within 0.52% in a very small range of moisture content (8.0-11.0%) for KS-282. For all other varieties, accuracy does not fall within 0.55% at any moisture range.

Table 2. The relationships between readings of different moisture meters and moisture content as determined by the Oven Standard Method for IRRI-6.

Moisture Meters	Regression Equation For Moisture Meter (X) To Oven Standard Method (Y)	Correlation Coefficient (r)	Coefficient of Determination (r2)	Standard Error of Slope (s)
Burrows-700	Y = 0.5373 X + 6.451	0.994 **	0.9880	0.018
Dole-500	Y = 0.6481 X + 5.086	0.951 **	0.9044	0.063
Dickey-john-DJGMT	Y = 0.6984 X + 3.458	0.999 **	0.9980	0.011
Motomco-919	Y = 0.1797 X + 10.65	0.975 **	0.9506	0.012
Insto-1	Y = 0.9931 X - 2.497	0.991 **	0.9821	0.040
Sinar Datatec-P25	Y = 0.8191 X + 1.205	0.993 **	0.9860	0.029
Kett Riceter-L	Y = 0.9998 X - 0.658	0.996 **	0.9920	0.028
Delmhorst G-6C	Y = 0.9027 X + 1.542	0.987 **	0.9742	0.044
Shizuoka CR-1	Y = 1.0530 X - 2.593	0.989 **	0.9781	0.047

** $p < 0.001$

Table 3. The relationships between readings of different moisture meters and moisture content as determined by the Oven Standard Method for KS-282.

Moisture Meters	Regression Equation for Moisture Meter (X) to Oven Standard Method (Y)	Correlation Coefficient (r)	Coefficient of Determination (r2)	Standard Error of Slope (s)
Burrows-700	Y = 0.5775 X + 5.809	0.991 **	0.9821	0.023
Dole-500	Y = 0.6191 X + 5.136	0.957 **	0.9158	0.056
Dickey-john-DJGMT	Y = 0.6605 X + 4.214	0.997 **	0.9940	0.016
Motomco-919	Y = 0.1594 X + 10.93	0.985 **	0.9702	0.008
Insto-1	Y = 0.7516 X + 3.977	0.993 **	0.9860	0.028
Sinar Datatec-P25	Y = 0.7587 X + 1.880	0.977 **	0.9545	0.050
Kett Riceter-L	Y = 1.0220 X - 1.259	0.996 **	0.9920	0.029
Delmhorst G-6C	Y = 0.7800 X + 2.701	0.974 **	0.9487	0.055
Shizuoka CR-1	Y = 0.8251 X + 1.408	0.976 **	0.9526	0.056

** $p < 0.001$

Table 4. The relationships between readings of different moisture meters and moisture content as determined by the Oven Standard Method for Basmati-385.

Moisture Meters	Regression Equation for Moisture Meter (X) to Oven Standard Method (Y)	Correlation Coefficient (r)	Coefficient of Determination (r2)	Standard Error of Slope (s)
Burrows-700	Y = 0.5057 X + 6.335	0.998 **	0.9960	0.009
Dole-500	Y = 0.6270 X + 5.317	0.958 **	0.9178	0.057
Dickey-john-DJGMT	Y = 0.5200 X + 6.016	0.990 **	0.9801	0.022
Motomco-919	Y = 0.1570 X + 10.92	0.975 **	0.9506	0.011
Insto-1	Y = 0.5854 X + 5.937	0.992 **	0.9841	0.022
Sinar Datatec-P25	Y = 0.6998 X + 2.936	0.937 **	0.8779	0.078
Kett Riceter-L	Y = 0.9973 X - 0.8125	0.983 **	0.9663	0.055
Delmhorst G-6C	Y = 0.9146 X + 1.402	0.985 **	0.9702	0.046
Shizuoka CR-1	Y = 0.9719 X - 1.422	0.989 **	0.9781	0.041

** $p < 0.001$

Table 5. The relationships between readings of different moisture meters and moisture content as determined by the Oven Standard Method for Basmati-Pak.

Moisture Meters	Regression Equation for Moisture Meter (X) to Oven Standard Method (Y)	Correlation Coefficient (r)	Coefficient of Determination (r2)	Standard Error of Slope (s)
Burrows-700	Y = 0.4708 X + 7.429	0.986 **	0.9722	0.024
Dole-500	Y = 0.5638 X + 6.518	0.970 **	0.9409	0.043
Dickey-john-DJGMT	Y = 0.5113 X + 6.580	0.975 **	0.9506	0.035
Motomco-919	Y = 0.1510 X + 11.25	0.967 **	0.9351	0.012
Insto-1	Y = 0.5710 X + 6.569	0.977 **	0.9545	0.038
Sinar Datatec-P25	Y = 0.7280 X + 2.568	0.989 **	0.9781	0.033
Kett Riceter-L	Y = 0.9859 X - 0.3702	0.992 **	0.9841	0.039
Delmhorst G-6C	Y = 0.8946 X + 1.290	0.972 **	0.9448	0.065
Shizuoka CR-1	Y = 0.8855 X + 0.2158	0.992 **	0.9841	0.035

** $p < 0.001$

Table 6. Moisture meters accuracy ranges against the Oven Standard Method for various varieties of rough rice (paddy).

Moisture Meters	Varieties			
	IRRI-6	KS-282	Basmati-385	Basmati-Pak
Burrows Digital Moisture Computer	13.0 - 15.0 (0.07 - 0.51)	12.6 - 14.8 (0.02 - 0.49)	11.8 - 13.8 (0.01 - 0.50)	13.0 - 15.0 (0.02 - 0.55)
Dole Digital Grain Moisture Tester	13.0 - 16.0 (0.02 - 0.54)	12.2 - 14.8 (0.03 - 0.50)	13.0 - 15.6 (0.02 - 0.50)	13.8 - 16.0 (0.02 - 0.50)
Dickey-john Grain Moisture Tester	09.7 - 13.1 (0.01 - 0.53)	11.0 - 13.8 (0.00 - 0.48)	11.6 - 13.6 (0.03 - 0.51)	12.4 - 14.4 (0.03 - 0.52)
Motomco Moisture Tester	12.5 - 13.7 (0.10 - 0.59)	12.5 - 13.7 (0.08 - 0.59)	12.2 - 13.7 (0.12 - 0.64)	12.5 - 14.0 (0.13 - 0.64)
Insto Farm Grain Moisture Tester	08.0 - 15.6 (2.55 - 2.60)	14.0 - 18.0 (0.00 - 0.50)	13.0 - 15.4 (0.03 - 0.55)	14.2 - 16.4 (0.04 - 0.48)
Datatec Moisture Analyser	08.0 - 10.0 (0.04 - 0.60)	08.0 - 10.0 (0.05 - 0.53)	08.0 - 11.2 (0.01 - 0.53)	08.0 - 11.2 (0.01 - 0.48)
Kett Digital Grain Moisture Tester	08.0 - 34.8 (0.68 - 0.66)	29.8 - 34.8 (0.49 - 0.60)	08.0 - 11.0 (0.75 - 0.80)	08.0 - 16.0 (0.48 - 0.60)
Delmhorst Crop Moisture Detector	10.8 - 21.0 (0.00 - 0.50)	12.2 - 14.4 (0.02 - 0.50)	10.6 - 22.0 (0.00 - 0.50)	08.0 - 17.0 (0.00 - 0.50)
Shizuoka Comet Run Moisture Meter	32.8 - 34.8 (0.75 - 0.85)	08.0 - 11.0 (0.01 - 0.52)	08.0 - 10.0 (1.65 - 1.70)	08.0 - 10.0 (0.70 - 0.93)

Note: Numbers in parenthesis show the difference between the Meter and Oven readings.

Table 7. Conversion chart for the Burrows-700 Moisture Computer against the Oven Standard Method for the use of IRRI-6.

METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE
8.00	10.75	17.00	15.59	26.00	20.42
8.20	10.86	17.20	15.69	26.20	20.53
8.40	10.96	17.40	15.80	26.40	20.64
8.60	11.07	17.60	15.91	26.60	20.74
8.80	11.18	17.80	16.01	26.80	20.85
9.00	11.29	18.00	16.12	27.00	20.96
9.20	11.39	18.20	16.23	27.20	21.07
9.40	11.50	18.40	16.34	27.40	21.17
9.60	11.61	18.60	16.44	27.60	21.28
9.80	11.72	18.80	16.55	27.80	21.39
10.00	11.82	19.00	16.66	28.00	21.50
10.20	11.93	19.20	16.77	28.20	21.60
10.40	12.04	19.40	16.87	28.40	21.71
10.60	12.15	19.60	16.98	28.60	21.82
10.80	12.25	19.80	17.09	28.80	21.93
11.00	12.36	20.00	17.20	29.00	22.03
11.20	12.47	20.20	17.30	29.20	22.14
11.40	12.58	20.40	17.41	29.40	22.25
11.60	12.68	20.60	17.52	29.60	22.36
11.80	12.79	20.80	17.63	29.80	22.46
12.00	12.90	21.00	17.73	30.00	22.57
12.20	13.01	21.20	17.84	30.20	22.68
12.40	13.11	21.40	17.95	30.40	22.78
12.60	13.22	21.60	18.06	30.60	22.89
12.80	13.33	21.80	18.16	30.80	23.00
13.00	13.44	22.00	18.27	31.00	23.11
13.20	13.54	22.20	18.38	31.20	23.21
13.40	13.65	22.40	18.49	31.40	23.32
13.60	13.76	22.60	18.59	31.60	23.43
13.80	13.87	22.80	18.70	31.80	23.54
14.00	13.97	23.00	18.81	32.00	23.64
14.20	14.08	23.20	18.92	32.20	23.75
14.40	14.19	23.40	19.02	32.40	23.86
14.60	14.30	23.60	19.13	32.60	23.97
14.80	14.40	23.80	19.24	32.80	24.07
15.00	14.51	24.00	19.35	33.00	24.18
15.20	14.62	24.20	19.45	33.20	24.29
15.40	14.73	24.40	19.56	33.40	24.40
15.60	14.83	24.60	19.67	33.60	24.50
15.80	14.94	24.80	19.78	33.80	24.61
16.00	15.05	25.00	19.88	34.00	24.72
16.20	15.16	25.20	19.99	34.20	24.83
16.40	15.26	25.40	20.10	34.40	24.93
16.60	15.37	25.60	20.21	34.60	25.04
16.80	15.48	25.80	20.31	34.80	25.15

Table 8. Conversion chart for the Burrows-700 Moisture Computer against the Oven Standard Method for the use of KS-282.

METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE
8.00	10.43	17.00	15.63	26.00	20.82
8.20	10.54	17.20	15.74	26.20	20.94
8.40	10.66	17.40	15.86	26.40	21.05
8.60	10.78	17.60	15.97	26.60	21.17
8.80	10.89	17.80	16.09	26.80	21.29
9.00	11.01	18.00	16.20	27.00	21.40
9.20	11.12	18.20	16.32	27.20	21.52
9.40	11.24	18.40	16.44	27.40	21.63
9.60	11.35	18.60	16.55	27.60	21.75
9.80	11.47	18.80	16.67	27.80	21.86
10.00	11.58	19.00	16.78	28.00	21.98
10.20	11.70	19.20	16.90	28.20	22.09
10.40	11.82	19.40	17.01	28.40	22.21
10.60	11.93	19.60	17.13	28.60	22.33
10.80	12.05	19.80	17.24	28.80	22.44
11.00	12.16	20.00	17.36	29.00	22.56
11.20	12.28	20.20	17.47	29.20	22.67
11.40	12.39	20.40	17.59	29.40	22.79
11.60	12.51	20.60	17.71	29.60	22.90
11.80	12.62	20.80	17.82	29.80	23.02
12.00	12.74	21.00	17.94	30.00	23.13
12.20	12.85	21.20	18.05	30.20	23.25
12.40	12.97	21.40	18.17	30.40	23.37
12.60	13.09	21.60	18.28	30.60	23.48
12.80	13.20	21.80	18.40	30.80	23.60
13.00	13.32	22.00	18.51	31.00	23.71
13.20	13.43	22.20	18.63	31.20	23.83
13.40	13.55	22.40	18.75	31.40	23.94
13.60	13.66	22.60	18.86	31.60	24.06
13.80	13.78	22.80	18.98	31.80	24.17
14.00	13.89	23.00	19.09	32.00	24.29
14.20	14.01	23.20	19.21	32.20	24.40
14.40	14.13	23.40	19.32	32.40	24.52
14.60	14.24	23.60	19.44	32.60	24.64
14.80	14.36	23.80	19.55	32.80	24.75
15.00	14.47	24.00	19.67	33.00	24.87
15.20	14.59	24.20	19.78	33.20	24.98
15.40	14.70	24.40	19.90	33.40	25.10
15.60	14.82	24.60	20.02	33.60	25.21
15.80	14.93	24.80	20.13	33.80	25.33
16.00	15.05	25.00	20.25	34.00	25.44
16.20	15.16	25.20	20.36	34.20	25.56
16.40	15.28	25.40	20.48	34.40	25.68
16.60	15.40	25.60	20.59	34.60	25.79
16.80	15.51	25.80	20.71	34.80	25.91

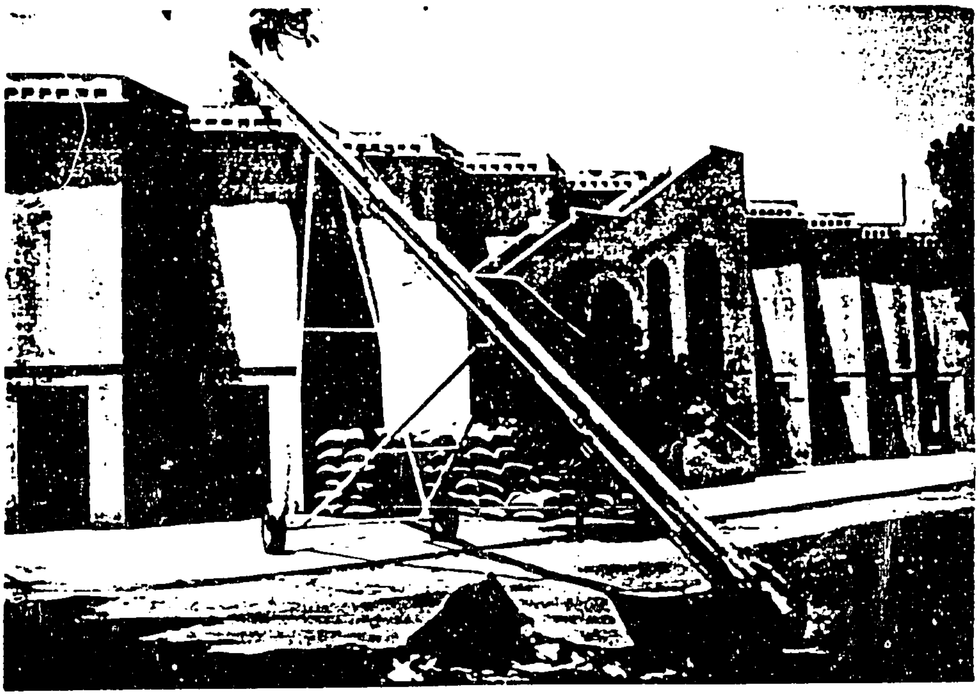
Table 9. Conversion chart for the Burrows-700 Moisture Computer against the Oven Standard Method for the use of Basmati-385.

METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE
8.00	10.38	17.00	14.93	26.00	19.48
8.20	10.48	17.20	15.03	26.20	19.58
8.40	10.58	17.40	15.13	26.40	19.69
8.60	10.68	17.60	15.24	26.60	19.79
8.80	10.79	17.80	15.34	26.80	19.89
9.00	10.89	18.00	15.44	27.00	19.99
9.20	10.99	16.20	15.54	27.20	20.09
9.40	11.09	18.40	15.64	27.40	20.19
9.60	11.19	18.60	15.74	27.60	20.29
9.80	11.29	18.80	15.64	27.80	20.39
10.00	11.39	19.00	15.94	28.00	20.49
10.20	11.49	19.20	16.04	28.20	20.60
10.40	11.59	19.40	16.15	28.40	20.70
10.60	11.70	19.60	16.25	28.60	20.80
10.80	11.80	19.80	16.35	28.80	20.90
11.00	11.90	20.00	16.45	29.00	21.00
11.20	12.00	20.20	16.55	29.20	21.10
11.40	12.10	20.40	16.65	29.40	21.20
11.60	12.20	20.60	16.75	29.60	21.30
11.80	12.30	20.80	16.85	29.80	21.40
12.00	12.40	21.00	16.95	30.00	21.51
12.20	12.50	21.20	17.06	30.20	21.61
12.40	12.61	21.40	17.16	30.40	21.71
12.60	12.71	21.60	17.26	30.60	21.81
12.80	12.81	21.80	17.36	30.80	21.91
13.00	12.91	22.00	17.46	31.00	22.01
13.20	13.01	22.20	17.56	31.20	22.11
13.40	13.11	22.40	17.66	31.40	22.21
13.60	13.21	22.60	17.76	31.60	22.32
13.80	13.31	22.80	17.86	31.80	22.42
14.00	13.41	23.00	17.97	32.00	22.52
14.20	13.52	23.20	16.07	32.20	22.62
14.40	13.62	23.40	18.17	32.40	22.72
14.60	13.72	23.60	18.27	32.60	22.82
14.80	13.82	23.80	18.37	32.80	22.92
15.00	13.92	24.00	18.47	33.00	23.02
15.20	14.02	24.20	16.57	33.20	23.12
15.40	14.12	24.40	18.67	33.40	23.23
15.60	14.22	24.60	18.78	33.60	23.33
15.80	14.33	24.80	16.88	33.80	23.43
16.00	14.43	25.00	18.98	34.00	23.53
16.20	14.53	25.20	19.08	34.20	23.63
16.40	14.63	25.40	19.18	34.40	23.73
16.60	14.73	25.60	19.28	34.60	23.83
16.80	14.83	25.80	19.38	34.80	23.93

Table 10. Conversion chart for the Dole Moisture Meter against the Oven Standard Method for the use of the Basmati-Pak.

METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE	METER'S READING	ACTUAL MOISTURE
8.00	11.20	17.00	15.43	26.00	19.67
8.20	11.29	17.20	15.53	26.20	19.76
8.40	11.38	17.40	15.62	26.40	19.86
8.60	11.48	17.60	15.72	26.60	19.95
8.80	11.57	17.80	15.81	26.80	20.05
9.00	11.67	18.00	15.90	27.00	20.14
9.20	11.76	18.20	16.00	27.20	20.23
9.40	11.85	18.40	16.09	27.40	20.33
9.60	11.95	18.60	16.19	27.60	20.42
9.80	12.04	18.80	16.28	27.80	20.52
10.00	12.14	19.00	16.37	28.00	20.61
10.20	12.23	19.20	16.47	28.20	20.71
10.40	12.33	19.40	16.56	28.40	20.80
10.60	12.42	19.60	16.06	28.60	20.89
10.80	12.51	19.80	16.75	28.80	20.99
11.00	12.61	20.00	16.85	29.00	21.08
11.20	12.70	20.20	16.94	29.20	21.18
11.40	12.80	20.40	17.03	29.40	21.27
11.60	12.89	20.60	17.13	29.60	21.36
11.80	12.98	20.80	17.22	29.80	21.46
12.00	13.08	21.00	17.32	30.00	21.55
12.20	13.17	21.20	17.41	30.20	21.65
12.40	13.27	21.40	17.50	30.40	21.74
12.60	13.36	21.60	17.60	30.60	21.84
12.80	13.46	21.80	17.69	30.80	21.93
13.00	13.55	22.00	17.79	31.00	22.02
13.20	13.64	22.20	17.88	31.20	22.12
13.40	13.74	22.40	17.97	31.40	22.21
13.60	13.83	22.60	16.07	31.60	22.31
13.80	13.93	22.80	18.16	31.80	22.40
14.00	14.02	23.00	16.26	32.00	22.49
14.20	14.11	23.20	18.35	32.20	22.59
14.40	14.21	23.40	18.45	32.40	22.68
14.60	14.30	23.60	18.54	32.60	22.78
14.80	14.40	23.80	18.63	32.80	22.87
15.00	14.49	24.00	18.73	33.00	22.97
15.20	14.59	24.20	18.82	33.20	23.06
15.40	14.68	24.40	18.92	33.40	23.15
15.60	14.77	24.60	19.01	33.60	23.25
15.80	14.87	24.80	19.10	33.80	23.34
16.00	14.96	25.00	19.20	34.00	23.44
16.20	15.06	25.20	19.29	34.20	23.53
16.40	15.15	25.40	19.39	34.40	23.62
16.60	15.24	25.60	19.48	34.60	23.72
16.80	15.34	25.80	19.58	34.80	23.81

PHOSPHINE FUMIGATION IN HEXAGONAL BINS



STORAGE TECHNOLOGY DEVELOPMENT AND TRANSFER PROJECT

14 - L MODEL TOWN EXTENSION

LAHORE

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PHOSPHINE FUMIGATION IN HEXAGONAL BINS

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STORAGE TECHNOLOGY DEVELOPMENT AND TRANSFER PROJECT

14-L MODEL TOWN EXTENSION

LAHORE 54600

PAKISTAN

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Introduction:

Provincial Food Departments (PFDs) have a number of units of bee-hive shaped bins called 'hexagonal bins' or "hexbins" for the storage of wheat in bulk. Each hexbin can take a maximum of about 36 tons of wheat. These bins were built in late 1940's and early 1950's in units varying in storage capacity from 500 to 3,000 tons at various places in the country. Total storage capacity of these bins in the country is for about 303,000 tons of wheat.

The current practice to protect the grain from insect infestation is by using AlP tablets at the dose rate of 2 tablets per ton of wheat. All tablets are placed on the top of the wheat surface. The bin is then sealed by closing the manhole with its gasket laced iron lid. The sealing is further supplemented by mud plastering around the top lid and the bottom spout opening. This method of fumigation is proved unsatisfactory after a critical study under Storage Technology Development and Transfer (STDT) Project because it does not achieve required exposure period resulting into failure of fumigation and requires refumigation to protect the grain in these hexbins. This practice not only increase the grain protection cost but it also amplify the resistance against phosphine in the insects.

Contrary to the general impression that insects breed mostly in the top layers of the grain, the studies done by STDT showed that they can live as deep as 5.50 meters inside the grain mass. The top grain layer however, has a higher population as compared to the lower layers. Thus, the study emphasize the necessity of the distribution of phosphine gas in all parts of the hexbin for the successful fumigation.

To improve the fumigation procedure for better insect control in hexbins, an improved method of fumigation is being described in this handout. By using this method the required concentration of phosphine gas can be retained in all parts of the hexbin for comparatively longer period of time without adding to the cost in the current procedure. This will help check and/or delay the onset of resistance to phosphine in storage pests which is feared to be spreading fast in this country due to the persistent inadequate distribution and retention of phosphine gas in the stored wheat.

Detailed procedure:

1. Fumigation with phosphine gas is the best strategy for the management of insect infestation in the wheat stored in hexbins.

2. Bins should be cleaned by dusting before loading of wheat.

3. No surface spraying of any insecticide is required inside the bins.

4. For phosphine fumigation, the currently adopted dosage rate of 72 AlP tablets per hexbin is adequate. This number of tablets should not be reduced even if a bin is not loaded to its full capacity of about 36 tons of wheat.

5. AlP tablets should not be placed on the surface of the grain as presently being practiced.

6. Fit the five rods with the **tablet applicator**. Each rod has a length of 0.9 meter and applicator is 30 cm long (Fig.1). The applicator can hold a number of 18 tablets at one time.

7. Divide the total number (72) of AlP tablets into two portions.

8. Fill the applicator with 18 tablets of one portion (36 tablets), close the shutter with thumb and insert it in the grain mass at its full length. Apply few jerks and then pull the applicator slowly out of the grain. Deposit remaining 18 tablets at same depth in similar way (Fig.2).

9. Unscrew four rods from the applicator, fill with 18 tablets of second portion and insert remaining rod alongwith the applicator in the grain mass. Repeat it for remaining 18 tablets.

10. After depositing all the tablets in the grain, close the lid of the opening hatch of hexbin immediately.

11. Seal the upper lid and bottom spout of the bin by applying mud plaster around them.

12. The bins under fumigation should remain closed for atleast 20 days after sealing.

13. Inspection of top grain layer should be undertaken every month for detection of any live insect. In case no live insects are found, the bins should immediately be resealed with mud plastering to prevent reinfestation.

14. If live insects are found, a refumigation should urgently be arranged except when wheat is to be issued for consumption in the immediate future.

Precautions.

1. Reclaim 18 tablets from the AlP tablet flask at one time and close it tightly.

2. Wear cotton gloves at the time of fumigation.

3. Atleast two persons should be engaged in application of tablets.

4. Fumigation should be done in clear weather at day time.

5. While inserting the AlP tablet applicator in the grain, no attempt should be made to pull until it reaches the required depth, otherwise the tablets will fall at unwanted depths.

6. After approaching the required depths, a few jerks to applicator will help drop the tablets in the grain.

7. Mud plastering should be inspected on second day of fumigation. If found any crack and leakage, should resealed properly to prevent loss of gas.

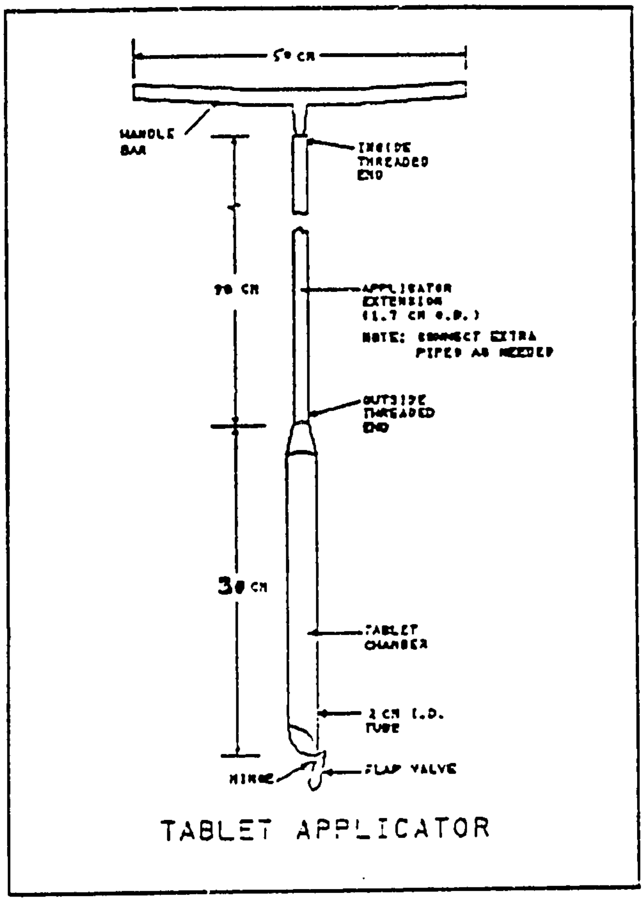

Figure 1. Measurement of the special AlP tablet Applicator for help of its local manufacturing.

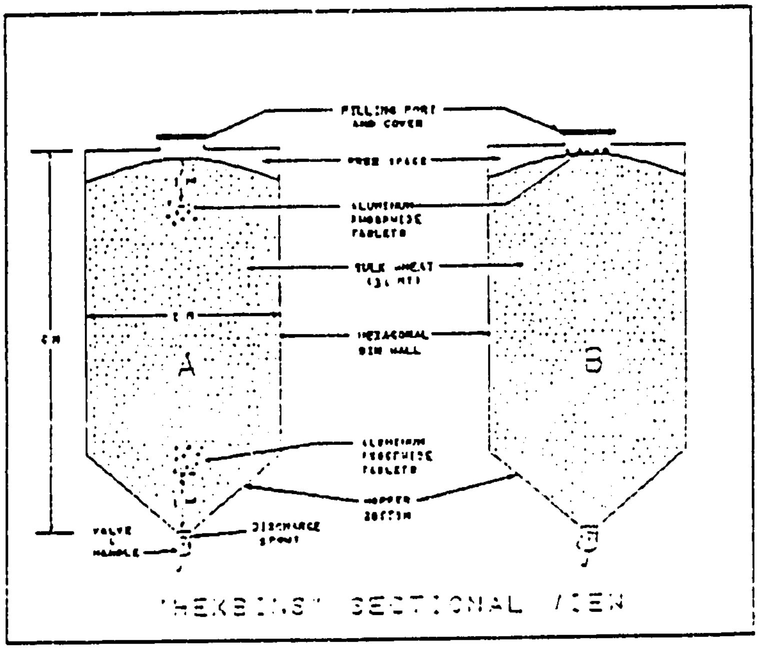

Figure 2. Longitudinal section of a hexbin showing the position of AlP tablets in the improved method of fumigation (A) as against the conventional method (B).

PHOSPHINE FUMIGATION IN OPEN BULKHEAD

STORAGE TECHNOLOGY DEVELOPMENT AND TRANSFER PROJECT

14 - L MODEL TOWN EXTENSION

LAHORE

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PHOSPHINE FUMIGATION IN OPEN BULKHEAD

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STORAGE TECHNOLOGY DEVELOPMENT AND TRANSFER PROJECT

14 - L Model Town Extension

LAHORE 54600

PAKISTAN

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INTRODUCTION

Besides other forms of bulk storage of wheat, open bulkhead is an important type of bulk storage facility in Pakistan. Of all these facilities, open bulkheads provide the cheapest method of bulk wheat storage in Pakistan.

The Pakistan Agricultural Storage and Services Corporation (PASSCO) installed the first open bulkhead in Pakistan at Okara in 1984 with Australian assistance. At present PASSCO has 21 open bulkheads while the Punjab Food Department (PFD) has 10 such structures. All bulkheads are presently located in the central Punjab. Their combined storage capacity is about 150,000 tones of bulk wheat.

The open bulkhead is a simple rectangular structure, made of moveable retaining walls anchored to an asphalted ground base. The retaining walls are made of corrugated iron sheets which are bolted on to the inclined steel frame trestles. Most bulkheads in Pakistan measure about 22.25 m x 52.73 m at the base and 23.77 m x 54.25 m at the top ends of the 2.29 m high retaining walls. A fully loaded bulkhead holds a massive heap of over 4,500 tones of bulk wheat.

Originally, portable inclined bucket elevators with a conveying capacity of 18 mt per hour were used to load bulkheads. However, due to their low conveying capacity and some other constraints, the use of these elevators was abandoned. Instead, manual labour was employed for loading and unloading of these facilities. Lack of durable and cheap cover and the absence of reliable and practical method of pest control were other major constraints which limited the use of these facilities.

To cover wheat in bulkheads, PASSCO and the PFD are now using imported fibre-reinforced plastic sheets. A portable grain pump having a much higher conveying capacity has also been introduced by Storage Technology Development and Transfer (STDT) project to solve the problem of loading the bulkheads.

To protect the wheat in the bulkheads from insect infestation, different pest management techniques were tested and a simple, reliable and practicable procedure was developed. By following this method a successful phosphine fumigation can be accomplished for open bulkhead.

DETAILED PROCEDURE:

1. Fumigation of open bulkhead requires considerable efforts, therefore, sufficient manpower should be available to complete the work rapidly enough to prevent excessive exposure to phosphine.

2. Fumigation should be done just after the completion of filling operation. This will save the energy and labour in removing and putting back the heavy plastic sheets.

3. Prepare AlP tablets at the dosage rate of 2 tablets per ton of wheat before fumigation.

4. Insert AlP tablets in grain mass with tablet applicator at about two metres apart. This ensures even distribution of the fumigant in the grain mass.

5. Deposit 20 to 30 tablets at each insertion point at depths ranging from about one metre in the periphery to 2.5 metres towards the center of the bulkhead.

6. After application of AlP tablets, cover the bulkhead with fiber-reinforced plastic sheets. Normally 5 - 6 plastic sheets are needed to cover the entire grain surface. The appropriate way to spread these sheets is described below:

   a. Spread two sheets one above the other on the grain surface starting from one end of the bulkhead (Fig. 1, Step No. 1).

   b. Place wheat filled gunny bags on the inner end of whole width of the sheets (Fig. 1).

   c. Lift up the upper sheet and spread on-ward, on the grain top covering the filled bags (Fig. 1, Step No. 2).

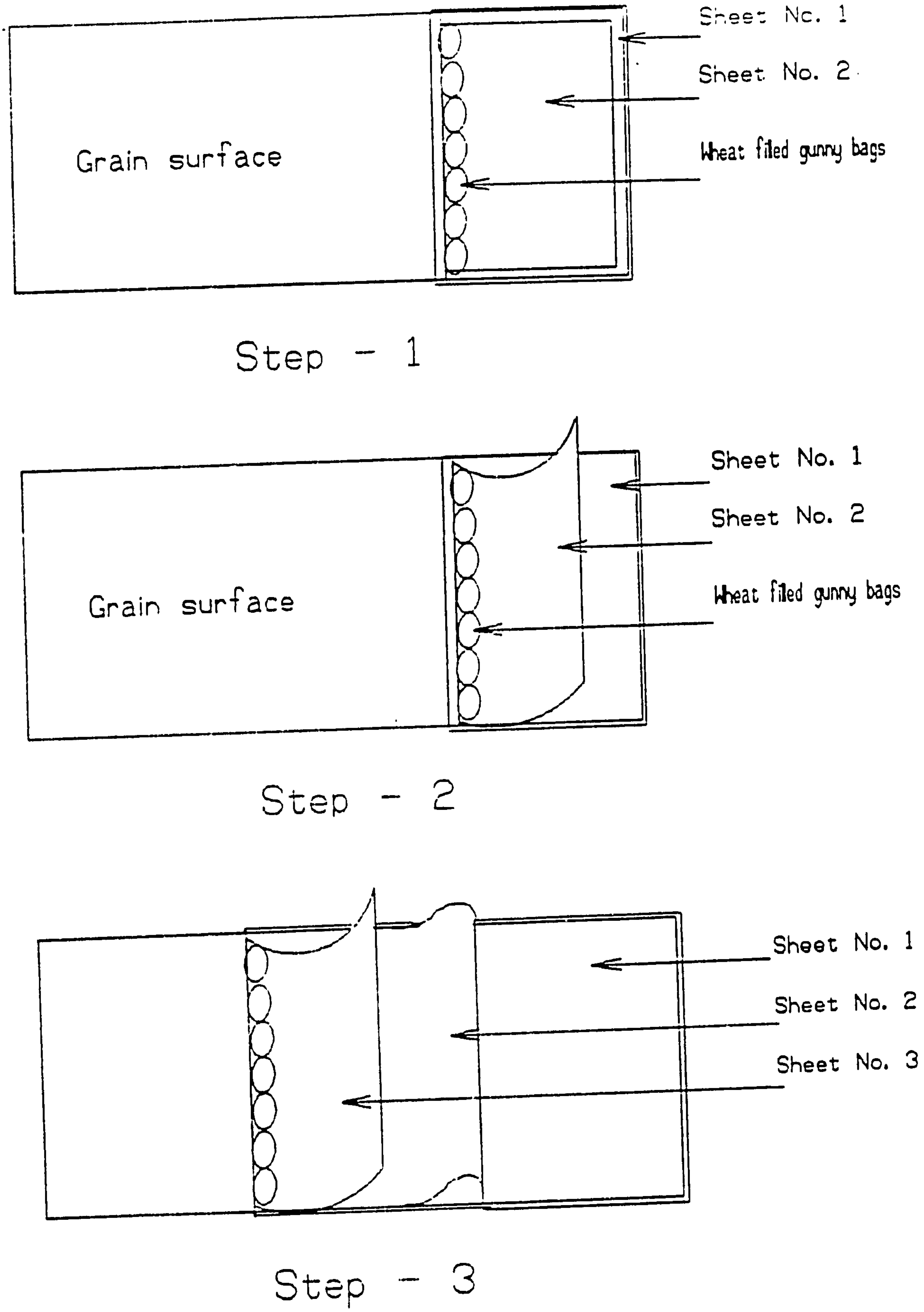

Fig. 1 . Various steps to cover the grain surface and make the bulkhead airtight with fiber-reinforced sheets.

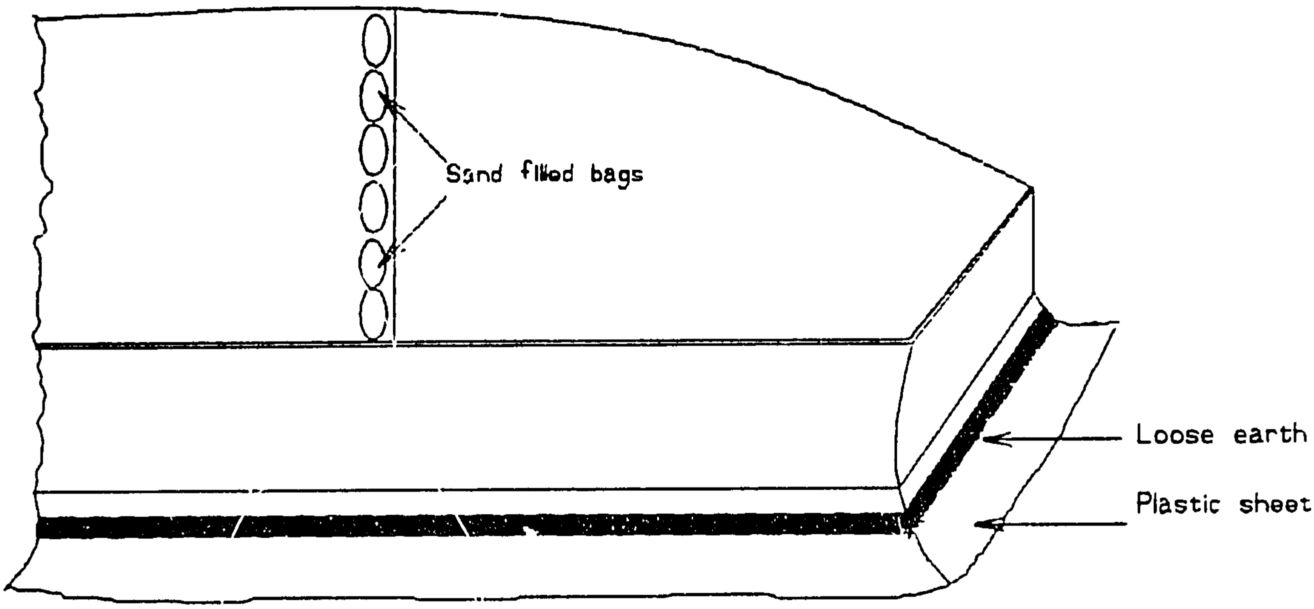

Fig. 2. Sketch of a corner of bulkhead showing placement of sand filled bags on top and loose earth on sheet/ground joint.

d. Spread the third sheet above the second one and place the bags on the other ends. Again lift the upper sheet and spread on the grain surface. By using this method, cover the whole grain surface (Fig. 1, Step No. 3).

7. If above mentioned method could not be adopted, place sand filled bags (sand snakes) on top of the overlapping sheets (Fig. 2).

8. Clamp the loose ends of the sheets with the retaining walls. If some non-sealable gaps noticed in the corrugated steel walls, drop and spread the loose ends of the plastic sheets on the ground and hold them with loose earth all around the bulkhead (Fig. 2).

9. Close all the leakage points in the retaining wall or plastic sheets with PVC self adhesive tape.

10. Keep the bulkhead sealed as long as possible.

11. Spraying the bulkhead with some residual insecticides before and after storing grain will help reduce the re-entry of insects from the surroundings.

SAFETY RECOMMENDATIONS:

1. The fumigation of bulkhead must be performed under the supervision of a trained person. Never allow uninstructed

person to handle phosphine formulations.

2. The fumigation in-charge should ensure the even distribution of tablets in the total grain mass. Special attention be given to the corners of the bulkhead.

3. Wear dry cotton gloves during application of AlP tablets.

4. Do not allow AlP tablets to contact with water.

5. Conduct fumigation during cooler period of the day.

6. Protect unused AlP tablets from excessive exposure to atmospheric moisture during application and tightly reseal the flasks after use.

Storage Technology Development and Transfer Project - Pakistan

IMPORTANCE OF GRAIN GRADING

BY

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March 2, 1992

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IMPORTANCE OF GRAIN GRADING[1]

Grain Grades

Grain grades are a listing of the characteristics or attributes of grains deemed important to the buyer and seller. Grades may include such factors as variety, moisture content, color, shape and size of kernel, insect damage, etc., as indicators of the suitability of grains for creating end products. All wheat is not created equal for specific purposes. (Figure 1.)

Grain Grading

Grain grading is the process of measuring specific lots of grains against grade specifications. This can be done by sensory means biting for moisture content, smelling for molds, insect damage, or visually for foreign materials, brokens, insect damage, etc. More sophisticated and consistent mechancial means are used where grades are inforced.

Why Grain Grading

The most valued attribute any product can have is consistency. That is, the atta, nan, chappati, or leavened bread should be the same today, tomorrow, and next week. Progressive millers build their reputation on this - the baker cannot have surprises or costly failures. The housewife does not want culinary disasters when serving her family - particularly the in-laws.

In Pakistan however, quality control and downstream processing are virtually unknown because of inability to control inputs - hence quality. Every wheat shipment is a virtual 'grab-bag' of the good, the bad, and frequently ugly. Millers try to compensate the best they can by cleaning, blending, and equipment adjustments, but these are mostly judgement measures based on long experience. Very few, perhaps less than 5 of the 300 plus flour mills have functional laboratories. Even these are not used regularly.

Is FAQ a grade?

The present FAQ grades originated in the grain exchanges that were common in Lahore, Lyliapur, Okara, Multan, and other cities prior to 1942. The FAQ then in use was developed for each exchange for each harvest season. At the beginning of harvest, a committee from the exchange would collect samples from the surrounding area, mix them in a dara or heap, then do an analysis for moisture, shrunkens, brokens, insect damage, etc. The result would be described as Fair Average Quality for the Grain Exchange.

[1] Richard C. Maxon, STDT/ASSP, Islamabad. Paper presented to Seminar Workshop on Grain Storage Management Research and Training, University of Agriculture, Faisalabad, 2-3 March 1992.

FAQ descriptions and samples would be sent to major buyers in distant locations. The buyers would then contact the Exchange and order shipments for future delivery - say October or November. When delivery was made, the product delivered would be compared with the sample. If the buyer was not satisfied that the shipment was FAQ, the grain exchanges had mechanisms for investigating and settling disputes. In this sense, the FAQ was serving the role and function of grades.

What is important to realize is that the marketing process is a flows. (Figure 2) Product - wheat is constantly moving forward toward the ultimate consumer. The market intermediaries, brokers, agents, processors, wholesalers, retailers, etc. are in essence purchasing agents for their immediate customers. They must know and understand what their customers want, and how to recognize it in commodities they buy. When the product flows forward, it is accompanied by information about its characteristics. This information can be in form of visual inspection of each lot before purchase, or in product descriptions or labels. In case of the latter, the buyer must have faith that the descriptions or labels are accurate.

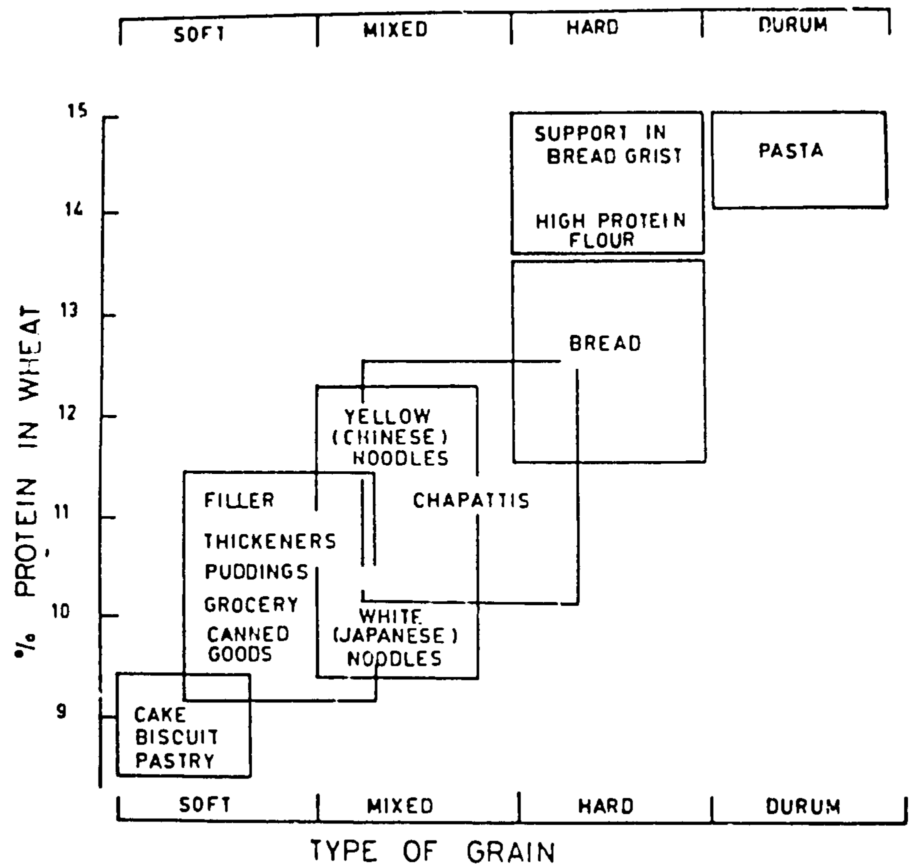
What returns in the flow? Payments, and information. When these are interrupted by false information, or distorted, such as through government controls or subsidies, the systems tend to break down. This is why appropriate grades are important for the producer, marketeer, and processor and consumer. Without them, trade and progress are virtually impossible. The present FAQ standards are nearly 50 years old. Further, they have never been recognized as standards by law, nor have any prescribed procedures for applications ever been developed. FAQ at present is in the eye of the beholder. Every year, the Food Departments and PASSCO reissue the FAQ specifications from the year before. The FAQ is neither fair to the producer or consumer. See annexes 1-3.

The FAQ has largely lost is meaning for several reasons. Wheat production is different. STDT surveys have indicated that wheat as produced is superior to FAQ standards. Producers and middlemen recognize this, and take steps to see that what is sold does meet FAQ standards - or less. FAQ as practiced encourages corruption and adulteration.

The time is right for change. The varieties have changed. The end uses are different - more breads, pastries, pastas, etc., less chapatis. The STDT has put forth several proposals for change, but little has happened thus far[2]. With increasing interest in quality control, bulk handling, and establishment of academic programs in grain storage, changes will come.

[2] Maxon, et. al, Impact of Fair Average Quality and No Loss Policy on Wheat Storage in Pakistan, Food and Feed Grains Institutes, Kansas State University, STDT Report No. 3, October 1989 revised.

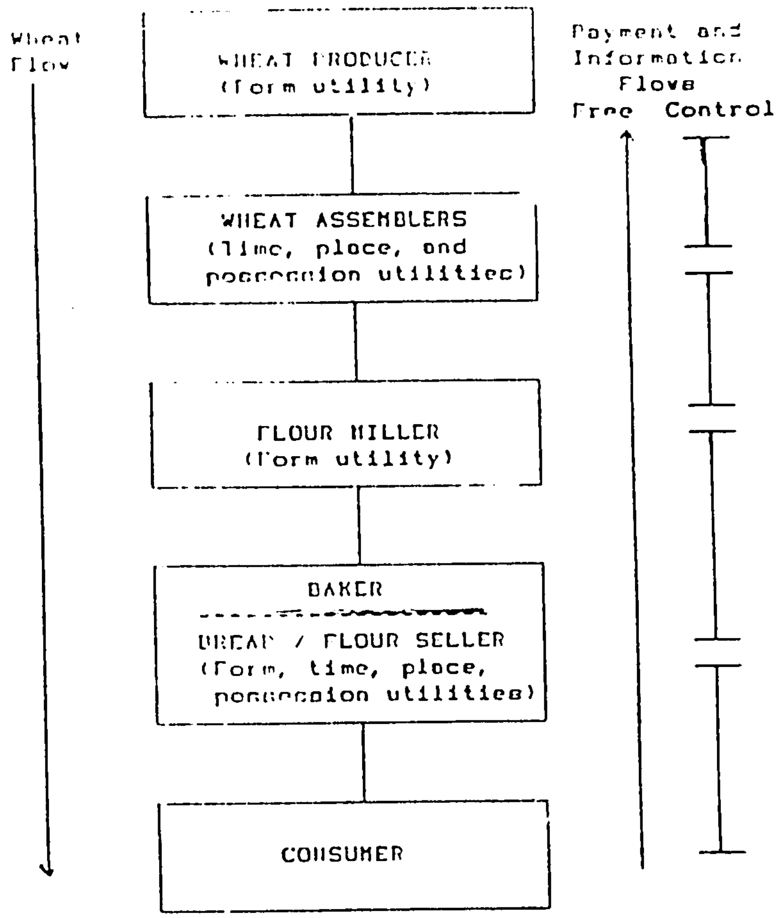
Figure 1.



Wheat types and the types of products made from them

Source: R. Carl Hosney
<u>Principles of Cereal Science and Technology</u>
American Association of Cereal Chemists, 1986

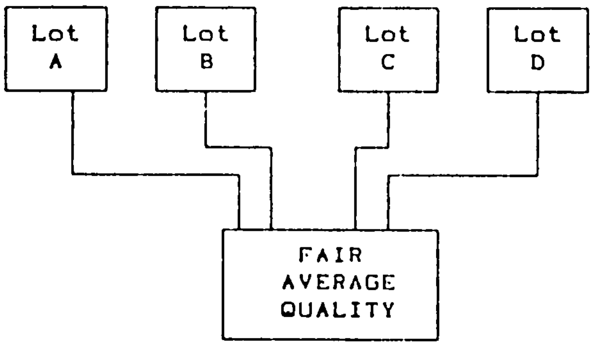
Figure [illegible]. The Wheat Marketing Chain



ANNEXES

FAIR AVERAGE QUALITY

Fair Average Quality or FAQ is a grain standard used in Pakistan for domestic purchases of wheat by the Provincial Food Departments and PASSCO. FAQ purportedly describes the average quality or normal quality characteristics of wheat that Pakistan farmers are capable of producing. Official procurement or support prices are issued in reference to wheat meeting FAQ standards. For procurement purposes, various quality characteristics are described, with minimum and maximum limits for each. Premiums or discounts paid for the characteristics meeting or exceeding the prescribed standards. Absolute limits are set, and wheat is to be rejected if limits are exceeded.



FAQ was orginally used to describe the quality of wheat available each season. FAQ was used for making contracts for future delivery, not cash or "spot" sales. In Pakistan, FAQ has has not been defined by law as an official grade standard, nor have any uniform testing procedures been adopted for the measurement of FAQ. The application of FAQ is totally subjective.

Many problems have arisen due to the use of FAQ as an official buying standard without legal status and subjective measurements of wheat quality.

- FAQ standards do not describe the quality of wheat being produced.

- Present FAQ standards and application are not equitable for producers.

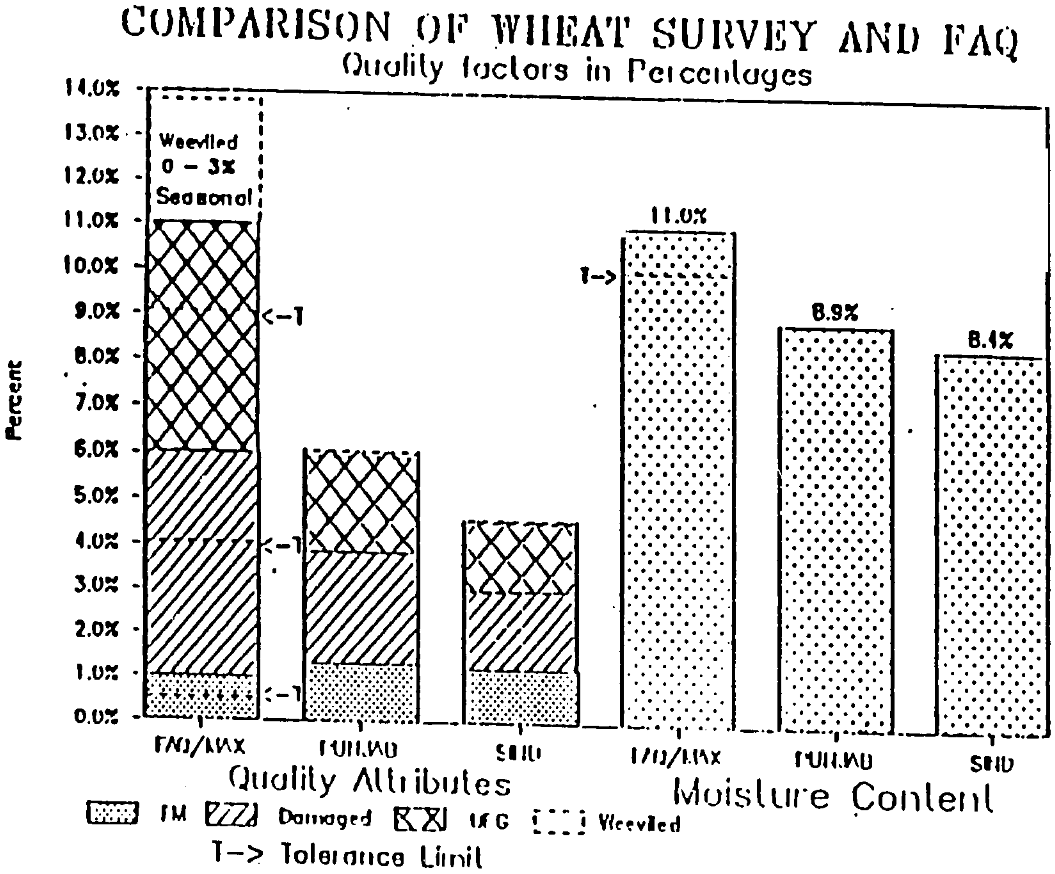
- Subjective application of FAQ creates conditions for fraud and malpractices in procurement.

- FAQ encourages the adulteration of wheat in procurement and storage.

SPECIFICATIONS OF WHEAT TO BE PURCHASED

S. No.	Defect	Tolerance Limit	Rejection Limit	Premium/Recovery for Less/Excess Impurities
1-	Dirt/Dust & other non-edible matters	0.5%	Over 1%	If 0.5% or less premium would be paid at 1%. Over 1% to 2% recovery & full value plus cleaning charges at Rs.20/- per 100 bags.
2-	Other Food Grains	3%	Over 5%	Over 3% to 5% recovery at Half Value.
3-	Damaged/shrivelled.	3%	Over 5%	Over 3% to 4% at Half value & over 4% to 5% recovery at full value.
4-	Weevilled new crop upto end of August.	Nil	Nil	Weevilled wheat not to be accepted.
5-	September & October.	0.5%	Over 1%	Over 1/2% to 1% at full value.
6-	November & December.	1%	Over 2%	Over 1% to 2% at full value.
7-	January & onward	1.5%	Over 3%	Over 1.5% to 3% at full value.
8-	Moisture Contents.	10%	Over 11%	

(MUKHTAR ALI BAIG)
General Manager(Field).



STDT/PMRI 1988 Survey of Wheat Quality

INEQUITIES IN FAQ PAYMENTS WITH "KARDA" SYSTEM

Producer	Foreign Matter Percent	Moisture Percent	Useable Wheat (kg.) 1/	Amount Paid 2/	Actual Value of Wheat 3/	Over / (Under) Payment /4
A	4.0%	12.0%	948.10	2,103.75	2,014.71	89.04
B	1.0%	10.0%	1,000.00	2,103.75	2,125.00	(21.25)
C	1.0%	8.0%	1,022.20	2,103.75	2,172.18	(68.43)

1/ Quantity of useable wheat delivered standardized to 10 percent moisture content and 1 percent foreign materials.
2/ Support price of Rs. 2125/Ton times 990 kg. (1T - 1kg/bag)
3/ Quantity of useable wheat times support price of 2125/T
4/ Actual value minus amount paid.

BND USE VALUE OF WHEAT WITH VARIABLE MOISTURE FOREIGN MATTER CONTENT AT COST OF RS.230/100KG.

Gain in kilograms per 100 kg. of wheat tempered to 14% moisture from wheat with varying moisture and FM content 1/

Initial FM Pct.	Initial Moisture Content 8.0%	9.0%	10.0%	11.0%	12.0%
1.0%	6.98	5.81	4.65	3.49	2.33
2.0%	5.91	4.76	3.60	2.45	1.30
3.0%	4.84	3.70	2.56	1.42	0.28
4.0%	3.77	2.64	1.51	0.38	(0.74)
5.0%	2.70	1.58	0.47	(0.65)	(1.77)
6.0%	1.63	0.52	(0.58)	(1.69)	(2.79)
7.0%	0.56	(0.53)	(1.63)	(2.72)	(3.81)
8.0%	(0.51)	(1.59)	(2.67)	(3.76)	(4.84)
9.0%	(1.58)	(2.65)	(3.72)	(4.79)	(5.86)

1/ Standardized to 10 percent moisture, 1 percent FM before tempering

Cost per 100/kg clean grain entering processing from grain purchased with varying moisture and FM content 1/

Initial FM Pct.	Initial Moisture Content 8.0%	9.0%	10.0%	11.0%	12.0%
1.0%	216.95	219.34	221.78	224.27	226.82
2.0%	219.17	221.58	224.04	226.56	229.13
3.0%	221.43	223.86	226.35	228.89	231.49
4.0%	223.73	226.19	228.71	231.28	233.90
5.0%	226.09	228.57	231.11	233.71	236.37
6.0%	228.49	231.01	233.57	236.20	238.88
7.0%	230.95	233.49	236.08	238.74	241.45
8.0%	233.46	236.03	238.65	241.33	244.07
9.0%	236.03	238.62	241.27	243.98	246.76

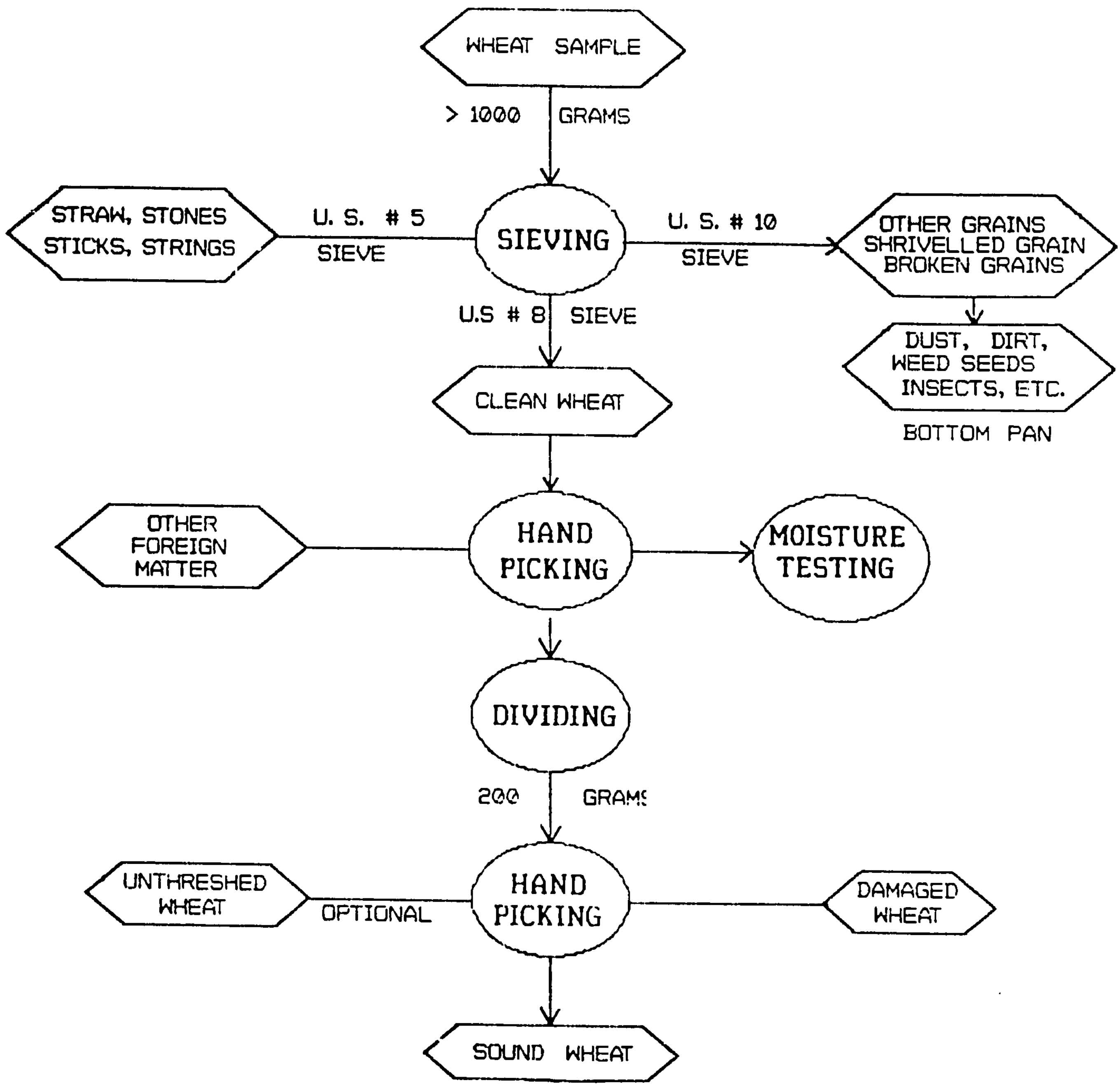
1/ Standardized to 10 percent moisture, 1 percent FM before tempering.

CONVERSION OF 100 KILOGRAMS OF GRAIN AS PURCHASED TO QUANTITY OF GRAIN STORED AT 9.0% MOISTURE CONTENT, 1.0% FOREIGN MATTER

GRAIN AS PURCHASED TO BE STORED @ % FM 1.0% (100 KG.)	% M.C. 9.0%	REDUCTION 1/ FM (KGS.) 2/	MOISTURE (KGS.) 3/	TOTAL WEIGHT LOSS (KGS.) 4/	NET WEIGHT KG. AFTER CLEANING & DRYING 5/	PURCHASE PRICE PER RS. 100/KG 240.00 6/	QUANTITY REQD. TO STORE 100 KGS. @ 1.0%FM 9%MC 7/
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3.0%	10.0%	2.02	1.08	3.10	96.90	233.00	103.2
3.0%	9.5%	2.02	0.54	2.56	97.44	234.00	102.6
3.0%	9.0%	2.02	0.00	2.02	97.98	235.00	102.1
3.0%	8.5%	2.02	-0.54	1.48	98.52	236.00	101.5
3.0%	8.0%	2.02	-1.08	0.94	99.06	238.00	101.0
3.0%	7.5%	2.02	-1.62	0.41	99.59	239.00	100.4
3.0%	7.0%	2.02	-2.15	-0.13	100.13	240.00	99.9
2.5%	10.0%	1.52	1.08	2.60	97.40	234.00	102.7
2.5%	9.5%	1.52	0.54	2.06	97.94	235.00	102.1
2.5%	9.0%	1.52	0.00	1.52	98.48	236.00	101.5
2.5%	8.5%	1.52	-0.54	0.97	99.03	238.00	101.0
2.5%	8.0%	1.52	-1.08	0.43	99.57	239.00	100.4
2.5%	7.5%	1.52	-1.62	-0.11	100.11	240.00	99.9
2.5%	7.0%	1.52	-2.16	-0.65	100.65	242.00	99.4
2.0%	10.0%	1.01	1.09	2.10	97.90	235.00	102.1
2.0%	9.5%	1.01	0.54	1.55	98.45	236.00	101.6
2.0%	9.0%	1.01	0.00	1.01	98.99	238.00	101.0
2.0%	8.5%	1.01	-0.54	0.47	99.53	239.00	100.5
2.0%	8.0%	1.01	-1.09	-0.08	100.08	240.00	99.9
2.0%	7.5%	1.01	-1.63	-0.62	100.62	241.00	99.4
2.0%	7.0%	1.01	-2.18	-1.17	101.17	243.00	98.8
1.5%	10.0%	0.51	1.09	1.60	98.40	236.00	101.6
1.5%	9.5%	0.51	0.55	1.05	98.95	237.00	101.1
1.5%	9.0%	0.51	0.00	0.51	99.49	239.00	100.5
1.5%	8.5%	0.51	-0.55	-0.04	100.04	240.00	100.0
1.5%	8.0%	0.51	-1.09	-0.59	100.59	241.00	99.4
1.5%	7.5%	0.51	-1.64	-1.13	101.13	243.00	98.9
1.5%	7.0%	0.51	-2.19	-1.68	101.68	244.00	98.3
1.0%	10.0%	0.00	1.10	1.10	98.90	237.00	101.1
1.0%	9.5%	0.00	0.55	0.55	99.45	239.00	100.6
1.0%	9.0%	0.00	0.00	0.00	100.00	240.00	100.0
1.0%	8.5%	0.00	-0.55	-0.55	100.55	241.00	99.5
1.0%	8.0%	0.00	-1.10	-1.10	101.10	243.00	98.9
1.0%	7.5%	0.00	-1.65	-1.65	101.65	244.00	98.4
1.0%	7.0%	0.00	-2.20	-2.20	102.20	245.00	97.8
0.5%	10.0%	-0.51	1.10	0.60	99.40	239.00	100.6
0.5%	9.5%	-0.51	0.55	0.05	99.95	240.00	100.0
0.5%	9.0%	-0.51	0.00	-0.51	100.51	241.00	99.5
0.5%	8.5%	-0.51	-0.55	-1.06	101.06	243.00	99.0
0.5%	8.0%	-0.51	-1.10	-1.61	101.61	244.00	98.4
0.5%	7.5%	-0.51	-1.66	-2.16	102.16	245.00	97.9
0.5%	7.0%	-0.51	-2.21	-2.71	102.71	247.00	97.4

1/ ASSUMES GRAIN IS CLEANED BEFORE DRYING
2/ 100-(100*(1.0-INITIAL FM.%)/(1.0 - FINAL FM%)
3/ (100-COLUMN 3)*((1.00-INITIAL MOISTURE %)/(1.0-FINAL MOISTURE %))
4/ (COLUMN 3) + (COLUMN 4)
5/ 100 - (COLUMN 4)
6/ (COLUMN 5 / 100) * BASE SUPPORT PRICE
7/ 100 / (100/COLUMN 5)

GRAIN QUALITY ANALYSIS FLOWCHART



COMPLETE QUALITY ANALYSIS TAKES ABOUT 10-15 MINUTES
FAQ ANALYSIS TAKES ABOUT 5-8 MINUTES

RECOMMENDATIONS

1. Adopt objective grading for all purchases

   Relate pricing to volume of useable wheat delivered, not total weight

   As a minimum, measure moisture, foreign matter.

2. Modify accounting systems to permit changes in volume based on objective measurements.

   Changes in volume to be made by management, not at godown level

   Measure and record loss levels due to insect activity, spoilage, etc.

3. Change management systems to place responsibility for maintenance of quality, volume, at managerial level, not at godown level.

   Trained professional management responsible for stock maintenance.

   Rewards and incentives for loss reductions.

4. Adjust release prices to reflect value in end use.

   Objective measures of quality upon release, moisture, FM, etc. (Milling yields can be tested by season, or for special purposes)

   Adjust prices to permit recovery of services performed, such cleaning, sizing, and bulk delivery.

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