Drying the grain
Its importance and common practices

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1. Introduction

Along with preparation by cleaning and selection, the drying of the grain is very important for keeping it and for the success of any storage method.

If moist grains are stored without letting air pass through it will heat up, breathe more quickly and thus produce additional heat and humidity. As a result, the grain will rapidly deteriorate. If the grain contains too much moisture the heat increases more quickly, fungi develop fast and the grain may proceed to germinate.

It has now been known for a long time that meat, fish and fruit can be preserved by being dried and subsequently used as foods. Once dried, they will not deteriorate although they may be stored for a long period of time. This is because vital processes occur very slowly when there is little humidity. The same is true of grains. Well dried grain will indeed not deteriorate at all.

This document describes the theory regarding humidity, air temperature and grain temperature, relative humidity and their interactions. Further, safe humidity levels for grains and how to achieve them are described.

1.1 What is moisture in grains?

Moisture in grains may be defined as the amount of water they contain inside. The moisture content is the quantity of water in a mass unit of the grain expressed as a percentage.

All grain has a certain amount of humidity, or moisture, inside the kernel, even if on sight it does not appear that way. It is possible to establish if a grain has moisture inside by cracking it with one's teeth. Grain containing humidity will never be hard because the water inside it keeps it moist and soft. The amount of humidity contained in grain depends mainly upon the weather conditions under which it is harvested and sold. Grain harvested during the rainy season may have more humidity than grain harvested under dry conditions. Grain hardens as the moisture contained within diminishes during the process of drying.

It is important to point out that upon being harvested some grain may contain more moiaruew than others. For example, new varieties of rice must be harvested before the grains become too dry, since otherwise they might drop to the ground. Both maize and rice are harvested at about 20% humidity. However, the maize may be left to dry in the field, whereas rice must be harvested immediately.

Moisture in the grain is water content that is difficult to notice.

1.2 Humidity in the air

Air also contains humidity in the form of vapor.

Air retains differing amounts of water, much as grains do. Hot air can hold greater amounts of moisture. On a hot day there may be a considerable amount of humidity in the air. Toward evening, the temperature becomes lower and the colder air cannot retain all the humidity it did during the day. Thus the humidity in the air decreases and dew is formed on the surface of the soil.

When the air is exposed to the sun during the day, its temperature increases and more humidity is retained. The air takes up humidity from the soil in the form of vapor.

Humidity in the air is vapor that is difficult to see.

1.3 Relative humidity

Relative humidity is the percentage of the amount of air in relation to the maximum amount of humidity that air can retain at a particular temperature. If the humidity contents remains equal and temperature increases, relative humidity declines. Relative humidity is important only for those who have instruments with which to measure it and can use their knowledge when it comes to drying grains.

Most small farmers do not have the necessary instruments to measure relative humidity. Still, useful information can be obtained if two (2) factors concerning air and humidity are understood.

1. Hot air can retain more humidity than cold air.

2. Air at any temperature does not always retain all the humidity it can. The amount of humidity it contains may change. When it rains the air will retain the entire amount of water possible (100% relative humidity).

1.4 How air and humidity interact with grains

Scientists say that grain is “hygroscopic”. By this they mean that it looses or gains humidity from the air that surrounds it.

Everything that contains humidity also has a pressure. This is the case with air and grain as well. The grain is dried under the sun’s rays because vapor of the humidity changes from a higher pressure in the moist grain to a lesser pressure in the air, until the grain and the air reach a balanced vapor pressure.

This can be explained by stating that both the grain and the air give and receive water until they reach a point of equilibrium. Upon there being greater moisture in

the grain, the amount of water will decrease. In other words, if there is more moisture in the grain than in the air surrounding it, the humidity caught in the grain will pass on into the air.

Therefore, the key to grain drying processes is placing the grain under the sun's rays or in a drying machine, so that the seeds come into contact with the hot air that contains less humidity than the grain. The heat in the air will cause the moisture in the grain to evaporate into the air.

It is important to know that drying will continue for as long as the air surrounding the grain can absorb more humidity than the grain. If the air contains a high degree of humidity, the grain will absorb it. It is essential to understand this, since it explains why it is necessary to keep the dry grain as isolated as possible from humidity and / or the air. Grain that is not kept in a closed receptacle will continue to exchange humidity with the air. During the rainy season the grain will take on humidity if left in an open receptacle. During the dry, hot season, the grain will tend to loose humidity.

1.5 Safe storage moisture content in grains

The grains that have been stored should not contain more than a certain amount of humidity. Chemical and physical changes are slowest in a product with low moisture content. Most fungi do not develop under 70% relative humidity. Although the amount of moisture that the grain may retain during storage changes, depending upon the conditions under which it is stored, certain percentages have been arrived at that ensure a margin of safety regarding the amount of moisture allowable in grain under storage conditions.

The following table shows that maize can be stored safely at 13.5% moisture content (13,5% water and 86,5% dry matter). The surrounding air temperature should range from 25^{o} to 30^{o} C, with a relative humidity of 70% (meaning that the air at this temperature can retain 30% more water than that which it is presently retaining). At this point under the conditions just described the grain of maize, beans or rice and the surrounding air will in theory not exchange humidity. This equilibrium of relative humidity is the condition that establishes good grain storage conditions. However, it is very difficult to establish and then keep grains stored under conditions in which the equilibrium is permanently maintained.

Type of grain	Maximum humidity contents for one (1) year of storage (or less) at a relative humidity of 70% and a temperature of 27^{o} C
Maize	13.5%
Rice with husk (paddy)	15.0%
Rice without husk (milled grain)	13.0%
Sorghum	13.5%

Beans	13.5%

Remember that these are maximum recommended moisture levels. Grain should be dried as much as possible.

2. How to dry the grain

2.1 In the field

Drying the grain begins as soon as the product is ripe for harvesting.

When the grain remains in the field, the dry air takes the humidity out of the grain. The drying process is faster if the air does not contain very much humidity and if there is wind. The hot air will then pass through the grain and dry it more quickly than cold air would. This can be explained for three (3) main reasons:

1. Hot air can hold more water than cold air; therefore, the warmer the air as it passes through the grain, the greater will be the amount of water it takes from the grain.

2. Water evaporates more quickly when it is hot. Thus, as the hot air passes through the grain the water on the grain's surface will evaporate more quickly.

3. The hot air makes the temperature of the grain itself increase. This makes the water held inside leave the grain quickly. The air absorbs the water that leaves the surface of the grain in the form of steam or vapor.

2.2 After the harvest

The three (3) points mentioned above (see 2.1) are also applicable to drying grain after it has been harvested. The air passes through all of the grain, picking up the water between the seed and on their surface. But the moisture that is contained inside the seeds must first come to the surface before it can be taken up by the air. Only dry air, upon passing through the grain, can replace the humid air and thus absorb more water from the grain.

This then is the principle upon which some of the drying methods are based: making dry or hot air pass through the grain so as to accelerate drying.

It is almost impossible to dry grains completely. The seed will always retain 10% of the humidity and it is therefore difficult to achieve total dryness. However, grain may be reliably stored with that amount of humidity in it. In many cases, efforts to eliminate the residual moisture may damage the grain.

Whichever method is used to dry the grain, it is important that the drying temperature not be too high, as this causes physical damage to the seeds. This

in turn will lead to a reduction in yield upon being ground up, as well as to a reduced protein content. For example, the maize used to produce oil will yield less oil. If the grain is to be used for sowing, it will not germinate, since high temperatures kill the seed's embryo.

The following are the maximum temperatures recommended to dry the grain without producing adverse effects:

Use	Maximum Temperature in ^{o}C
Maize for production of flour	60^{o}C
Grains for sowing	40^{o}C
Rice for food	45^{o}C
Beans for food	35^{o}C

The temperature at which grain is dried will depend upon the use it is to be put to. Drying grains at low temperatures usually results in better quality than when they are dried at high temperatures. Low temperatures should also be used when drying very moist grain. It is better to take a little longer to dry the grain than to run the risk of damaging or even roasting it.

3. Different ways to dry grains

Farmers should take several things into consideration before deciding which method to use for drying their grain harvest. The following are some of the considerations to keep in mind:

Is the drying method being used at present working well?
How long would it take to install a new drying method?
Could a new drier be well maintained?
Could it be repaired were it to break down?
Is there sufficient time available to operate it?
Will the investment in the drier be paid off quickly through grain sales?
Would it be better for a group of small farmers to get together and buy a drier among all of them?

3.1 Solar methods

3.1.1 For drying small amounts of grain

Place thin layers of grain upon tray-shaped sieves which can be easily transported and stacked upon each other beneath a roofed structure overnight so as to protect the grain from dew or rain.

Build the sieves with a cloth or wire mesh bottom with small holes and place them in such a manner they are not in contact with the soil. The cloth or wire will

let the air travel freely throughout the grain and it will therefore dry quickly. Store the tray-shaped sieves at night so as to avoid exposure to humidity.

3.1.2 Drying grain in the sun using plastic sheets

Use a piece of polyethylene 10m long by 3m width or several smaller pieces which together add up to the aforementioned dimension. The polyethylene sheet should be thick and preferably black in color.

Build an earthen platform upon which to place the polyethylene sheet. If it is to be placed on the ground, use earth to make a border along the edges so as to protect the grains from water.

Make sure there are no stones, wood or other objects that may puncture the plastic, since it can easily be torn.

Place the polyethylene sheet in the prepared spot.

Use posts to tie down the plastic sheet's corners and edges.

Place the clean grain upon the sheet surface in layers no thicker than 5 cm.

Turn the grain over frequently so that it dries more quickly due to exposure to the wind and the sun.

The rake or whatever tool is used to turn the grain over should not have pointed ends, as these may cause damage to the plastic and the grain.

Cover the grain overnight by placing it at one end of the plastic sheet and folding the rest of the plastic over it.

Another way of covering the grain is by placing another plastic sheet over it.

It is recommendable to fasten the corners and edges of the plastic to the ground so that it cannot be picked up by the wind.

3.1.3 Drying grains in the sun using a patio with a cement floor

Much as in the situation described in point 3.1.2 above grain can be dried on a cement platform. Remember that the grain must be turned over frequently so that it dries more quickly and evenly. If the grain being dried is to be used for seeds it is recommended to turn the grain over permanently, so that the cement floor temperature not rise above 40^{o}C.

The advantage of drying grain in the sun is that it is an inexpensive and easily manageable method.

3.2 Drying grain in a crib

The crib is a structure made of sawed or round wood, bamboo, etc., and is used to dry maize on the cob out in the open by taking advantage of natural ventilation to store the cobs for 3 or 4 months. A crib consists of legs with rat-guards, a floor, walls and a roof. The legs should be at a height of at least 100 cm above the ground surface; the walls and the floor are built with wooden posts or studs at such a distance from each other that the cobs cannot fall through, while leaving enough space to ensure proper ventilation. The roof is built from any adequate material, such as zinc sheets, tiles, grass, etc. The width of the structure should be 70 cm, and height from the floor may vary from 150 to 200 cm. The length will depend upon the amount of maize to be stored.

The crib allows the farmer to harvest the maize as soon as it is ripe. Upon removal of the husk, the maize on the cob is separated into good and bad cobs. The good ones are placed inside the crib**.** A few layers of insecticide should be spread about. The cobs are piled loosely inside the crib. This will allow the air to pass through and dry the maize until the grains can be removed from the cob and stored safely in a metal silo.

The crib protects the maize from rain, rodents, birds and fungi. The treatment with insecticide will protect it from insects for 3 or 4 months. By using the crib the usual loss that occurs when maize is left to dry in the field can be avoided. Since harvesting can be done early, the field is free to plant a second short-cycle crop.

It is easy to build such a crib and a plan accompanied by instructions can be found in the *POSTCOSECHA* booklet titled “The Crib: Construction and Management”.

The advantages of having a crib are that it is easy to manage, inexpensive to build if construction material can be found in the area and requires no specialized personnel for operation.

3.3 Drying grain artificially

Artificial drying uses combustion energy and electrical or mechanical methods to increase air temperature. Some systems have heaters or ventilators to move both hot and dry air. There are many different designs and types of such machines. Medium size dryers are best used by small cooperatives and farmers (see Fig. 1). These run on shelled cobs, rice husks, organic material or petroleum to increase the temperature of the air and its drying potential.

Other dryers are built and sold for purposes of drying larger amounts of grain. In general these can be divided into batch dryers and continuous flow dryers. Whichever method is used, artificial drying offers the following advantages and disadvantages:

Air exit

Drying grain
Perforated floor
Dryer wall

Hot air Burner Outside air

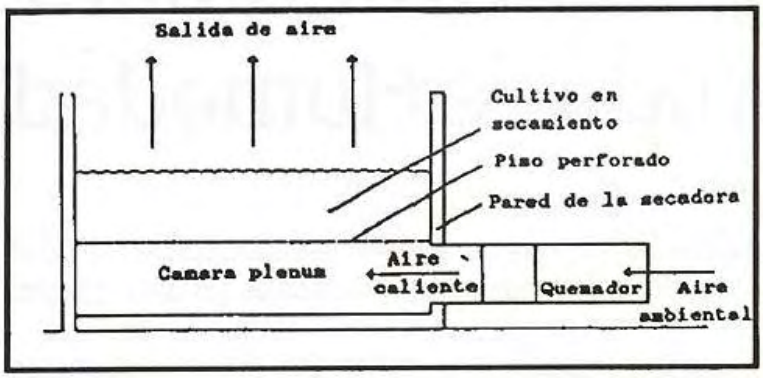

Figure 1. Plan for a batch dryer (FAO 1985)

Advantages:

Uniform drying is achieved by controlling the temperature and ventilation. The method is quick and can be operated automatically.

Some of the systems are portable, while others can be operated by using the motor of a tractor.
This drying equipment comes in a wide capacity range and are the most efficient and accepted method to dry great quantities of grain.

Disadvantages:

High temperatures and the degree of air flow demand trained personnel to operate the system.

The initial investment is high as it includes the cost of the equipment.

These dryers are useful only for big farms that produce large quantities of grain, as they have a high cost in terms of energy consumption.

4. Testing the grain for safe storage moisture content

There are various ways, using electronic devices, to measure the moisture contained in grains. Unfortunately none of these systems is simple or cheap.

An experienced farmer can know if the grain is dry enough for storage. The method used to determine this may vary between regions and type of grain. However, the most common methods used by experienced farmers are as follows: (1) squeezing the grain with the thumbnail to determine how hard it is (dry grain is difficult to squeeze); (2) breaking the grain with one's teeth to be certain it is sufficiently hard (dry) for storage; and (3) the method using salt that is described in the Manual for Manufacturing Metal Silos for Grain Storage, pages 121-123, as follows:

5. Observations

Whatever drying method is used, the grain will always seek to be in "equilibrium" with its surroundings. In general, at a given relative humidity, cereals have higher levels of humidity in equilibrium than pulses or grains that are rich in oil.

Maize can be safely stored when the moisture content of the grain is no higher than 14%. For beans this should be 13%.

In coastal zones with high relative humidity it is recommendable to dry the grain quickly on platforms or patios as soon as it ripens. If this is not feasible, due to climate conditions, it will become necessary to use artificial drying methods.

After the grain is dried it is recommended that it be stored in metallic silos or barrels placed beneath a roof and in the coolest parts of the house. It is important to stress that when grains are to be stored in closed structures such as a metallic silo it is crucial that they be well dried. For safe storage it is necessary to always store dry, fresh grain.