SORGHUM FLOUR PRODUCTION MANUAL

FOR

COMPATIBLE TECHNOLOGY INTERNATIONAL (CTI) BURR GRINDERS

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INTRODUCTION

The importance of sorghum in human nutrition and food security

The grinders of Compatible Technology International (CTI) were brought to El Salvador in 2009, for a project of CENTA-INTSORMIL/USAID to promote the grinding of sorghum for human nutrition. In 2011, ten of these grinders had been installed in small bakers associations, individual bakers, or persons producing ethnic drinks based on roasted and ground cereals. These people had been trained in sorghum use for human nutrition at the food technology laboratory of CENTA. The grinders are being used in areas were the access to other foods is limited and were sorghum can help to improve the nutritional status of the population.

Sorghum has a large potential in the effort to reduce malnutrition because it is locally produced and can be processed in very healthy foods. For that reason it has been used to substitute milk in times of scarcity, to feed elder or sick persons because of the minerals it contains and in general as a resource in case of poverty or a bad harvest of corn. Sorghum also has important dietary values for its content of fiber and antioxidants and is recommended for diabetics and celiacs because it has no gluten and its carbohydrates digest slowly. Both the availability and the nutritious quality offer important benefits for the rural communities.

INTSORMIL, CENTA and COMPATIBLE TECHNOLOGY INTERNACIONAL (CTI)

INTSORMIL is a collaborative research program of the universities of Kansas, Nebraska, Ohio, Purdue and Texas A&M with the financial support of US-AID. CENTA is the national agricultural research and extension institute of El Salvador, with activities in genetic improvement of corn, bean and sorghum varieties. Several sorghum varieties have been released and distributed among the farmers and the use of sorghum for human nutrition has been demonstrated and promoted to their families and people with a small food processing business.

COMPATIBLE TECHNOLOGY INTERNACIONAL is a nonprofit organization from Minnesota, aimed at providing appropriate technology solutions for developing countries, mainly in postharvest and health topics. Their grinders are designed to produce fine flour on a small scale and at a low cost. This manual is the result of the interaction of the three organizations mentioned and of the experience obtained from grinding sorghum with the CTI grinders and training people at the Food Technology Laboratory of CENTA.

1. SORGHUM GRAIN

Sorghum has been grown for centuries in India and China and in many African countries, where it originated. It is not well know when it has brought to the Americas but it probably was brought together with the slaves from Africa. The plant grows very well in tropical conditions such as much light and limited access to water and soil nutrients. In Central America it is often used in an inter- cropping or after-cropping system, because it picks up the fertilizers left over by corn, the main crop, and is more resistant to drought, so if the corn fails, sorghum is there to take over and rescue the farmer´s family. It is fed to animals when the corn crop is abundant and used in tortillas and other human foods when not, so it has clearly an important food security function. Unfortunately it receives usually little attention and inputs, and often its market price is very low compared to its nutritional value. Table 1 shows the nutritional values of sorghum, rice, wheat, and maize. One objective of INTSORMIL and CENTA has been to promote the regular use of sorghum in human nutrition, given that the varieties of El Salvador present excellent characteristics to do so.

Table 1. Comparative nutritional values of four cereals

Food grain	Protein (g)	Fat (g)	Ash (g)	Crude Fiber (g)	Carbs (g)	Energy (kcal)	Ca (mg)	Fe (mg)	Niacin (mg)
Rice (integral)	7.9	2.7	1.3	1.0	76.0	362	33	1.8	4.3
Wheat	11.6	2.0	1.6	2.0	71.0	348	30	3.5	5.1
Corn	9.2	4.6	1.2	2.8	73.0	358	26	2.7	3.6
SORGHUM	**10.4**	**3.1**	**1.6**	**2.0**	**70.7**	**329**	**25**	**5.4**	**4.3**

Source: 1982. USDA/HNIS. 1984.

In general the grain is formed by three parts: pericarp, germ and endosperm (Fig. 1). The endosperm has two possible forms, floury and hard, and their proportions differ per variety. Hard varieties have mostly hard endosperm, soft varieties mainly floury endosperm.

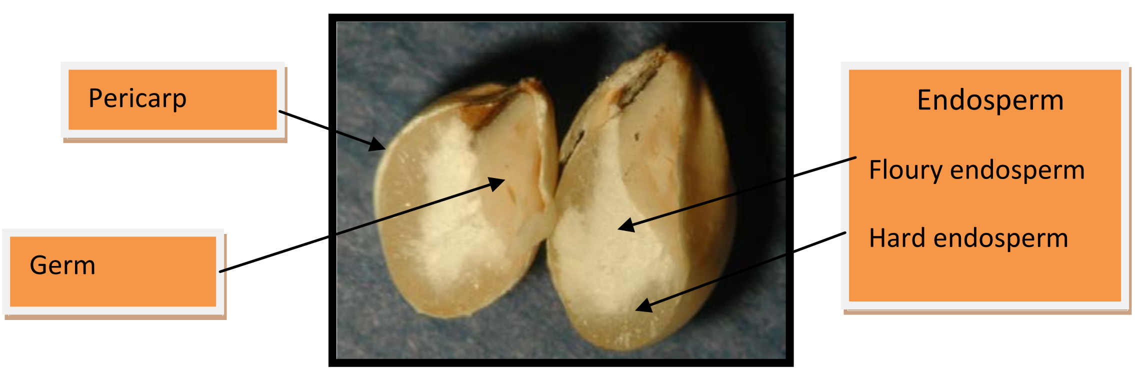


Fig. 1. Sorghum grain´s structure (left: hard variety, right: soft variety)

Table 2. Nutritional values of the sorghum grain parts

Part	% of grain´s weight	Protein	Ash	Fat	Carbohydrates
Complete grain	100	12.3	1.67	3.6	73.8
Endosperm	82.3	12.3	0.37	0.6	82.5
Germ	9.8	18.9	10.4	28.1	13.4
Pericarp	7 9	6.7	2.0	4.9	34.6

Source: Hubbard. Hall and Earle. 1990

When the grain is ground without separating part of it, the flour is called "complete" and has a nutritional value close to the grain. Complete flour has the highest levels of minerals, fat and fiber, but is usually is also the darkest and the fiber present does not permit bread to rise as expected. Therefore bread is usually made from refined flours, from which germ and pericarp fractions have been separated during the milling process. To obtain very white flour more complicated milling processes are used, with sieves and other means to get out undesired parts of the grain. In the case of complete sorghum flour the color of the grain must be as white as possible so as to not obtain dark flour.

Besides of the grain color, the presence and the color of the glumes are also important. The glume is a small "cap" that covers part of the grain and can be of different colors, depending on the variety. Most of the glumes are removed during threshing, but not all, and when ground together with the grain they affect the flours color. If the glumes have a tan color, it hardly affects flour color. If glumes are purple the resulting flour may be a grey color. Fig. 2 shows the main glume color types. The "testa" is a dark layer below the pericarp of some sorghum varieties, that contains condensed tannins, and that reduces the digestibility of protein and iron. The tannins act also as anti-oxidants, which are expected to be beneficial for the health, because they can reduce the aging of the body cells protecting them from free radicals.

Figure 2. Testa and glumes of different colors.

Table 3. Desirable sorghum grain properties for white sorghum flour

Properties	Preferred for white flour
Glume color	Tan
Pericarp color	White or ivory
Testa	No testa
Grain texture	Soft. (Hard in case of decorticating)
Pericarp thickness	Thin

The grain quality desirable for sorghum flour depends upon the equipment and the final product specifications. For small grinders the soft grains will produce fine flour most easily, while the decorticating process applied in larger plants requires hard grains, in order to resist the abrasion applied to remove the pericarp. Usually white flour is preferred, but in some cases it does not matter or a dark color looked for.

Anyway it is not always possible to find the optimal grain quality so often the operator has to adjust the process to the prime material's quality. Farmers choose varieties with good agronomic performance, and do not always expect their sorghum to be used for human nutrition. Therefore, when buying sorghum for flour, a balance has to be found between the preferred, the available, and the price.

2. GRAIN MILLING

2.1. Operations prior to grinding

2.1.1. Grain cleaning

If the sorghum has been threshed mechanically or has been cleaned after threshing, it can be stored and processed as it is. If the sorghum has been threshed on the soil it often comes with small stones, soil, stalks and other types of foreign matter that have to be eliminated. The cleaning equipment normally includes screening to take out the bigger parts and sieving to take out finer parts such as dust, broken grains and small insects. An air flow can take away glumes and foreign matter of the same size as the sorghum grain. Similar effects can be obtained with manual operations using sieves and winnowing manually. Very dirty grain can be washed with clean water: the heavy parts will sink and light parts will float and can be easily separated. Afterwards the grain has to be dried which takes several days of sun. Drying takes a lot of work and is excluded in the rainy season. The best is to buy clean grain in order to reduce the cleaning previous to grinding.

2.1.2. Washing sorghum grain

Sorghum grain can be washed on a small scale using deposits and a strainer. The light impurities, glumes and insect damaged grains will float and can be separated from the top. It may be necessary to change the water until it stays clear, and a spoonful of bleach will reduce the contamination by microorganisms. The sorghum can be separated from the water using the strainer, and must be quickly dried in order to avoid the development of moulds. In a layer of 2 cm on a plastic as shown in Fig. 3 it will take a pair of days to reduce the humidity back to around 12%, depending on the conditions.

Washing and separating the water | **Drying** | **Clean, dry sorghum**

Fig. 3. Washing and drying sorghum

2.1.3. Sorghum grain storage

In order to distribute the crop during the whole year, grain storage facilities are required, such as metal (Fig. 4) or plastic containers which can be hermetically sealed. That is important to permit an efficient application of the pest control fumigant (e.g. aluminum phosphate), and to keep humidity and insects out. The humidity of the grain has to be below 13%. An efficient pest control is strictly required, because sorghum is very susceptible to insect attack, and normally the grains come infested from the fields. The grain must be inspected every two months and if something improper is detected, action should be taken in order to save the grain.

Fig. 4 Moving a metal grain storage bin

2.1.4. Grinding principles

Grinding cereals is a very ancient activity and the equipment used has been changing with the availability of power and with the expectations of the customers. In general there are two types of grinders: by attrition and shear, and by impact. The most common examples are the burr mill and the hammer mill.

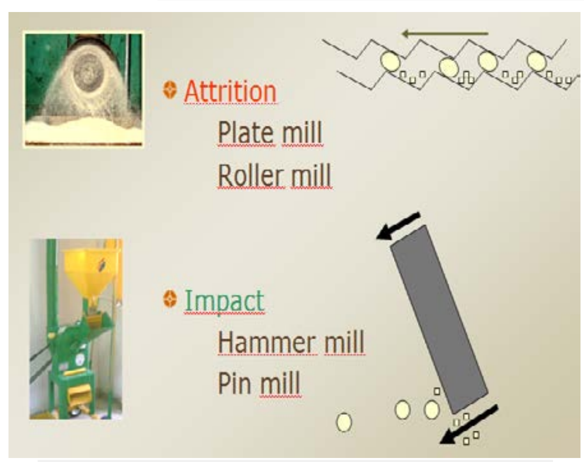


Fig 5. Grinding principles with burr and hammer mill.

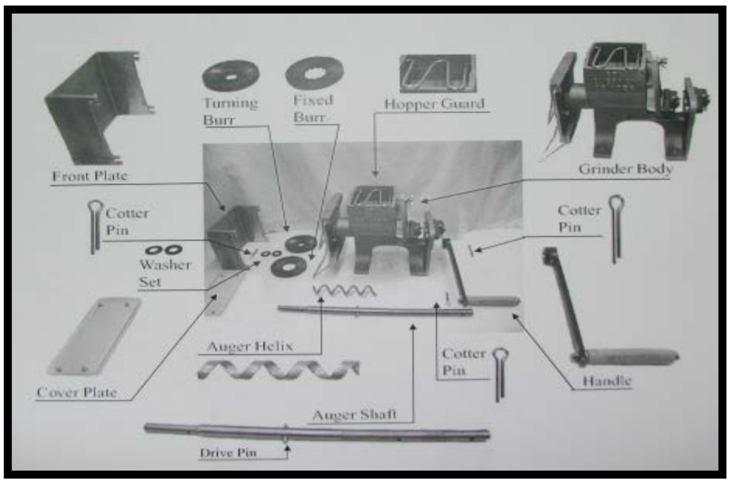
3. GRINDING EQUIPMENT

3.1. CTI grinders and their parts

The grinders of CTI are designed to reduce cereal grains to flour or to paste. The construction and materials of the body are not complicated so that persons interested in building one can do so with local materials. The discs are the main part and are made of hardened steel, so that the wear is very little and they can last many hours of operation. They cannot be regrooved with common tools, so once worn out they have to be replaced, which is after a couple of years of normal use. The burrs have 64 grooves in the center and 160 grooves on the outside. The grinders have a crank to be operated by one person, but it usually is powered by a small electric motor, from 3/4 to 1.5 horsepower. Therefore, a couple of pulleys and a belt are used, in a way to get 300 rpm for ¾ HP to 500 rpm for 1.5 HP

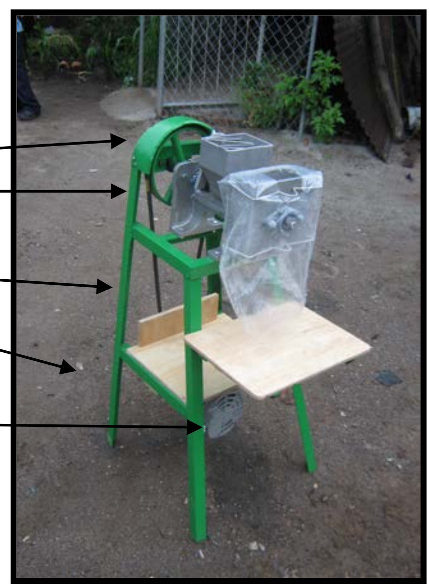
Fig. 6. Parts of the grinder.

(From CTI Omega VI Grinder Training Manual)



Parts needed for the motor operated grinder

- Belt protector
- Pulleys (ϕ 6 cm and ϕ 20 or 24 cm)
- Belt
- Stand (may be of metal or wood)
- Electric cord, switch, plug
- Hopper
- Motor



3.2. CTI grinder types

There are 3 models:

- Omega VI (cast aluminum body)
- Ewing (steel plate body)
- Wooden body

The discs, shaft and helix are the same for all grinders.

EWING

WOODEN MODEL

Fig 7. Ewing and wooden model grinders

3.3. Use of CTI grinding burrs (discs) in locally fabricated grinders

In El Salvador, CA a small cast iron grinder is used to produce corn paste for tortillas. It is very popular and it´s smallest version presents the possibility of working with the CTI burrs, as its original burrs are very similar in size. Some adjustments had to be made to the shaft and the suspension of the burrs. After that the grinder can be changed to grinding flour in a few minutes without special tools. Adjustments were made to the hopper in order to regulate the flow of material to the helix and thus reduce the need of a person to feed the grinder. In the first pass the opening to the helix is reduced and in the last passes the flow of flour is improved by an agitator and anti-bridging edges. Fig. 8 shows the grinder and the adjustments made to the body and the hopper.

Fig. 8. Corn grinder from El Salvador, adaptor for CTI discs and the modified hopper (l to r).

3.4. UTENSILS USED TO OPERATE THE CTI GRINDERS

Together with the grinder a few implements can be used to help the operator. In the best case the grinder will be able to work without intervention of the operator, except filling the hopper and being present to supervise the proper operation of the grinder. Most of all the flow of product to the helix and to the grinding burrs has to be regulated. Too much product will choke up the grinder and stop it, too little product will let the plates touch each other and make them heat up and wear out. In the beginning a plate with a small opening below the hopper will reduce the flow of sorghum grains. In the last passes the flour often forms bridges in the hopper and will not flow without help of the operator. Some form of agitator and plates to avoid compaction of the flour can reduce the need for the operators´ help.

Another aspect is the particle size and the color of the flour, that can be improved taking out coarse particles and fiber by means of sieves with mesh numbers from 30 or 40 (openings from 0.6 to 0.4 mm). After the initial passes a portion of the pericarp may be sieved out, when only 5 to 10 % of the product is retained on the sieve. The largest particles are mostly from pericarp and glumes, and are often darker. The flour that passes the sieve will be finer and whiter. The sieves may be shaken by hand if there is little product, or some type of equipment can be used. With mesh numbers around 40, the sieving is relatively easy, but the flour will need to be passed through the grinder repeatedly to reduce its particle size further. Meshes around 80 can do the final sieving, but are much slower.

Other helpful tools are scoops to charge the hopper, a plastic funnel to guide the product and deposits to receive it. An amp meter is very useful to check the load of the motor and to charge it to its full capacity. A brush and a piece of tube will help to clean the grinder, swiping or blowing residues out of the grinder. Table 5 shows most of the utensils mentioned.

3.5. COSTS OF THE CTI GRINDER

The costs of the grinder and it´s stand in 2010 are shown in table 7. They may vary depending on the materials used and the costs to import CTI parts. Except the hardened steel plates (burrs) and the aluminum body of the Omega VI grinder, the parts can be locally purchased and assembled. CTI can provide blueprints of the Ewing and the wooden model that are most appropriate for local construction.

Table 5. Utensils that can be used with the CTI grinder

Item	Example	Function
Brush, soft and hard Piece of plastic hose		Cleaning of the grinder after use. The hard brush to clean the discs, the hose to blow away flour.
Agitator shaken by the hélix. The spring type is most efficient		Moving the flour down when it is already quite fine

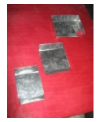
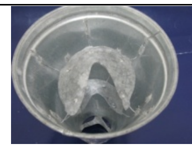
Small deposit or scoop, Big deposit		Small one to feed the grinder by hand, big one to fill the hopper or to receive the product.
Metal plate with a small opening	  	Reducing the flow of grain in the first pass.
Hopper, with retaining baffles, and an opening at its base	 	Storing material and feeding it to the grinder. An opening permits inspection.
Plastic bag fixed to the outlet, opened at the bottom or not		Receives or guides the product from the outlet and reduces the loss of product.
Amp meter		Checks the current consumed by the motor.
Sieve		Retains coarse particles of the flour.

Table 6. Characteristics to consider when deciding upon the type of grinder to acquire

Characteristics	Units, aspects
Capacity	Pounds or kg per hour, usually of grain
Manpower required	Grinders per operator
User friendliness	Experience and effort required
Energy consumption	kW and kWh per 1000 kg
Yield	% of flour from grain weight
Cleaning needs	Operator time and tools needed
Maintenance needs	Wearable pieces, cost to change them
Safety	Risk of accidents, noise, vibrations
Cost of investment	Total value of the equipment
Operating cost	Cost per kg of grain processed or flour obtained
Expected life time	Years
Pay back period	Years

Table 7. Approximate costs of the CTI grinders and the stand (in US $)

Item	Omega VI	Ewing	Local grinder
Pair of plates (burrs)	60	60	60
Grinder body	350	200	250
Shaft and helix	90	90	-
Motor (1.5 HP, open)	150	150	150
Stand and hopper	200	200	200
TOTAL	**850**	**700**	**660**

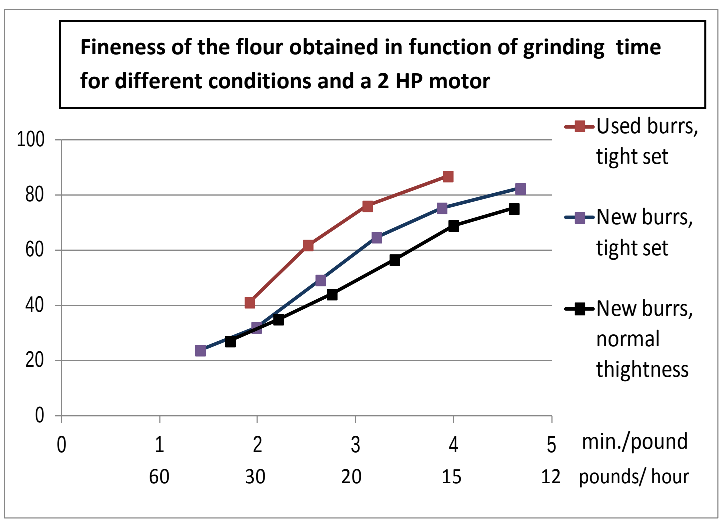
3.6 Grinding capacity

The output of the grinder depends on several factors, first of all of the turning speed of the discs (rpm), which is defined by the motor speed and the pulleys' sizes. The motor power (HP or kW) limits the speed and also the tightness of the discs as it affects the force required from the motor.
For small motors (¾ to 1 HP) and low speeds (300 rpm) the expected production of fine sorghum flour is around 15 pounds of sorghum per hour. With a bigger motors (1.5 to 2 HP) and higher speeds (up to 500 rpm), around 25 pounds of fine flour may be expected. That is with 4 to 6 passes through the grinder. In each pass an output of about 1 pound per minute for small motors and up to 2 pounds per minute for bigger motors is normal. Obviously the output depends also on the feed rate that should be close to the grinding capacity of the discs, in order to avoid under or overfeeding. With manual feeding it is easy to adjust the feed rate (add no more than what the auger helix is taking in). With the hopper the feed rate can be regulated by the utensils and the type of auger helix. When forcing too much material through tight burrs, they will choke up and the helix will probably be deformed. Too little product will cause a sharp noise and wear of the burrs.

If relatively coarse flour or only breakage of the sorghum is expected, the capacity can be two to four times more, depending on the coarseness and the material.

The heating of the discs and the flour limit the power that can be applied, it is not recommended to use more than 2 HP, and a reasonable tightening of the discs.

The grinding capacity depends also very much on the material being ground, basically the texture (hardness) of the grain in the case of sorghum, and its condition (roasted, dry or tempered). Fig. 9 shows the increase of the flour´s fineness (its % of particles smaller than 180 micron or # 80), during the grinding time. Each line represents a different material and each dot the result in consequent grinding passes (not all are shown).



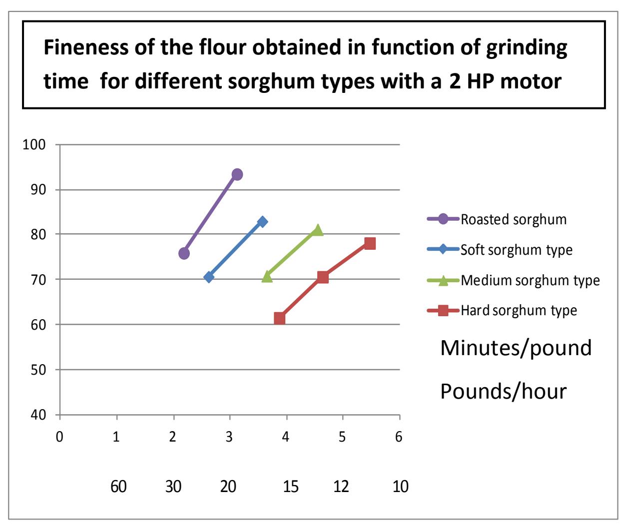


Fig. 9. Effect of different grinding conditions and materials on the fineness of the flour (% of weight passing a # 80 sieve)

4. SORGHUM FLOUR PRODUCTION

The expectations of the users of sorghum flour vary depending on the objectives of the final customers. If sorghum is used as a substitute for wheat flour in baking, normally white, fine and low fiber flour is required. If healthy, more natural flour is asked for, “complete” or “whole” sorghum flour is an excellent source because of its high content of fiber, minerals and anti-oxidants of the grain.

4.1. Complete sorghum grinding

When nothing is eliminated during the process, the flour presents the same nutritional values as the grain, with a high content of fiber and minerals. The CTI grinder on its own can produce fine flour in 3 to 5 passes, depending on the feed rate and the grain structure.

4.1.1. Initial grinding

The sorghum grains are small and spherical, which makes them flow easily to the grinding burrs. It is recommended to limit the flow in order to avoid overfeeding, which will stop the motor. Feeding manually is a good method. Otherwise a plate with a small hole can be placed over the helix, so that the hopper can be filled without overfeeding. The thin helix should be used and the burrs should be tightened moderately. Doing so, less coarse flour will be obtained without overworking the motor. The tightness of the grinding burrs is regulated by a screw that forces the shaft and the rotating burr to the fixed burr.

4.1.2. Reduction of the particles

In the following passes the flour´s particles size is further reduced. The flour will warm up due to the friction it is exposed to. The temperature is a good indicator of the grinding action and the pressure on the burrs. It will rise with each pass (unless it is cooled in between), but should not get hotter than what the operator’s fingers can stand. If that happens, the burrs are too tight and should be loosened a bit to avoid problems. Another way to check the tightness is moving the shaft by hand; it should not be too hard to do so.

4.1.3. Refining the flour

Depending on the grain type, the feed rate and the tightness of the burrs, the flour can be sufficiently fine in three to four passes for porridge and some bakery uses that don´t need a very fine flour. When fine flour is needed, additional refining will be required.

4.1.4. Additional refining

Depending on the particle size expected, one or two more passes will be necessary. As the material is already quite fine, it will not readily flow down, and tends to compact in the cone of the hopper. That may cause irregularities in the feeding of the burrs, which will run “dry”, producing a sharp noise and wearing out quickly.

To improve the material flow several things can be done:

- The operator can feed by hand and loosen or push down the flour when needed
- The thick helix can be used to increase its capacity and the movement of the agitator (normally the thin helix is used)
- The hopper can be equipped with baffles that support the flour
- An agitator can be introduced in the hopper, so that it jumps on the rotating helix

The last two items probably will eliminate the need of the operator to feed the grinder manually. Some people prefer to do so, and in all cases the operator should be supervising the process. The flour can get quite warm as explained. Ventilating it between the grinding passes will help to control the temperature and to dissipate water vapor. If not, the vapor will condense on cooler parts of the grinder and form lumps of moist flour. Ventilating somewhat the grinding burrs and the discharge also helps to prevent this. After finishing, the warm flour should be left open for some time for the same reason.

4.2. Sorghum grinding combined with sifting

4.2.1. Sifting

At some stages of the milling process it is relatively easy to take out undesirable parts of the product by sifting. In the case of sorghum it may be the pericarp parts and the glumes, to be separated from the flour, or coarse endosperm particles that need further grinding to be returned to the flour. The size of the openings is defined by the mesh number (openings per inch), or the openings size in millimeters or microns. The fabric is fixed to a frame that is shaken in one or another way. Fine flour contains a lot of very fine particles that stick to the screen and can block it completely, especially when the openings are small. Therefore it is easier to sift off pericarp particles and glumes in the early stages of the process. To pass fine flour through a high numbered mesh (e.g. # 80), a vigorous agitating mechanism is required and therefore it can´t be done by hand for even small quantities.

4.1.6. Sifter types

Industrial sifters are used to separate materials by size on a large scale. It is not easy to find equipment for small operations such as what a CTI grinder can handle. If the sifting is done only occasionally and with less than 10 pounds of flour, it can be done by hand. Sieves can be built from locally available materials. Only a frame and metal or plastic mesh of the available size and a bag or deposit to catch the fines are needed. Suspending the same simple sieve can reduce the human effort and a shaking mechanism make the unit work on its own. For continuous operation a cylindrical sieve with rotating brushes is an option and not so difficult to build. The design of these small scale sifters can be a reduced and simplified copy of the large scale units. Fig. 10 shows some of them and some small scale alternatives.

Fig. 10: Industrial sifters: Cylinder type, Vibrating screen type, Circular moving screen



Small scale sifters: Half cylinder, Suspended frame Manual sifting



Table 8. Mesh to micron conversion

U.S. Mesh	Microns
10	2000
20	841
30	595
40	420
50	297
60	250
70	210
80	177
100	149

5. OTHER GRINDING PROCESSES

5.1 Tempering

In some cases the humidity of the grain is increased in order to improve the separating of pericarp particles. The water will make the pericarp more resistant so that it´s pieces will be larger so more easily sifted. When moistened, the grain will not move so quickly through the grinder, which will reduce the number of passes required, which may be helpful when grinding grains with a hard texture.
Usually the moisture is adjusted to 15 %. A specific quantity of clean water is added to the dry grain in a mixing device and agitated until it is evenly distributed. A rest time of 8 hours permits the water to move into the grain and soften the materials. A formula is used to determine the quantity of water to be added based on the weight of the dry grain and its initial moisture (For 15 % final humidity). For other humidity percentages substitute 15* by the final % desired).

(Water to be added = dry grain weight x (15* **–** % initial humidity) **/** (100 – 15*)

When grinding tempered grain care should be taken not to tighten the discs very much, because the material is stickier and the discs will be choked up more easily. More vapors will be generated during grinding so the flour has to be ventilated during and after grinding. In order to be able to separate clean and big pericarp parts, it is recommendable to grind with relatively little pressure on the discs, and to take care not to overfeed.

5.2. Roasted grains

Several recipes in El Salvador use roasted cereals and sorghum is an excellent grain for that because is develops good aroma and flavor during the roasting process. The grain and pericarp structures from roasted products are more brittle and weak, so no separation of pericarp is done. For drinks the flour is expected to be very fine (< 200 microns), so 6 to 7 passes are applied.

5.3. Mixtures with oil bearing seeds

There are some very popular drinks in El Salvador based on ground and roasted cereals and spices. Often they are ground with water for instant consumption. When ground dry, the powder can be stored and sold, which makes it an attractive economic activity. Several of the seeds used, such as sesame and peanut contain considerable amounts of oil which quickly causes the choking up of the burrs. To avoid this, a few practices may help:

- The mixtures should not be too rich in oil containing seeds, so that the cereal can absorb the oil.
- The proper roasting is important to reduce the humidity of the seeds
- Roasted seeds must be kept in a sealed container, in order to avoid the absorption of moisture
- If sugar is ground at the same time, the temperature of the powder may not raise much; otherwise the sugar will get very sticky and fill the burrs.
- Clean the burrss with water after grinding sticky mixes, assuring to dry them immediately after.

WATER MAY BE USED ON REMOVED BURRS ONLY. NO WATER MAY BE USED ON THE GRINDER BODY! (The ball bearings and electric parts can be damaged by moisture)

6. FLOUR QUALITY CONTROL

In order to check the quality of the flour several aspects have to be taken into account (Table 9).

Table 9. Flour quality factors and the methods to measure them

Characteristic	Method
Particle size	Standard sieves, balance
Color (whiteness)	Spectrophotometer, color charts, reference samples
Fiber content	Chemical analysis
Humidity	Laboratory analysis
Nutricional values	Chemical analysis
Insects	Shelf life trials
Shelf life	Shelf life trials
Behavior in use as ingredient	Trials in laboratory or in preparing recipes

Most of them need time and laboratory equipment to be determined exactly. There are however several simple and rapid methods that can give a good idea of the flour's qualities. Some are explained below.

6.1. Quick methods to assess the particle size.

6.1.1. Method 1. Sensing with fingers and mouth.

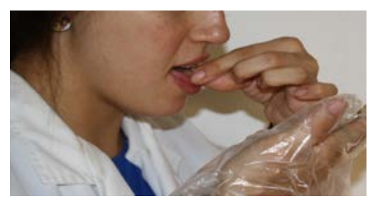


Fig. 11. Sensing the flour fineness

The size of the biggest particles can be detected taking a bit of flour between the thumb and index finger or on the hand. Taking some flour in the mouth and sensing between tongue and mouth ceiling. Ideally it readily "dissolves" without leaving sandy particles.

6.1.2. Method 2. Mixing with water.

A teaspoon of flour is mixed with two teaspoons of water in a plate or similar shallow deposit. The big and dark particles get more visible as the fine particles are washed away.

Fig 12. Different samples of flour in wáter : A : coarse, B : medium, C : fine flour

6.1.3. Method 3. Washing flour in fine mesh pouches.

A teaspoon of flour is put into a small pouch made of a fine fabric. The pouch is kept closed and washed in a deposit with a few liters of water or under faucet. The fine particles are washed away by the water and the coarse particles can be observed. The pouches can be dried to keep the sample for weighing or comparing with standards (Fig. 13).

Fig. 13. Comparing coarse particles retained in pouches

Fig. 14. Dough balls of five different samples

6.1.4. Methods to compare the flours color

Method 1. Color samples. In order to compare colors a set of samples can be kept so that a new lot can be compared to previous ones or samples with the expected whiteness. Color charts can be used; one of them is printed below.

Fig. 15. Color chart

6.1.5. Method 2. Color of a dough ball.

A tablespoon of flour can be mixed with a bit of water and kneaded into a dough ball. The color and the elasticity of the ball are representative of the results of using the flour in dough. See Fig. 14.

7. FLOUR PACKAGING

Warm flour must not be enclosed in sealed containers or plastic bags because the water will condense and concentrate in cooler spots. Paper bags will absorb part of the condensed vapor; plastic bags will get small water droplets on the inside. The droplets can initiate the development of molds. The flour should have moisture content below 15%; otherwise mold will begin growing and show up a few weeks afterwards. If the flour has high moisture and is still warm, it can be ventilated to reduce its moisture content. Otherwise sun drying will be needed, with the risk of infestation by insects.

Good quality dry sorghum flour can last for four months at ambient temperatures without changing taste or smell. It should be kept in cool, dry places, protected from insects, rodents and other forms of contamination.

8. CLEANING THE GRINDER

As all food processing activities, the grinding of flour has to be done in clean conditions, in order to guarantee a good quality product that will not get spoiled before a few months. The grinder must be cleaned before a period of rest, in order not to leave residuals that will attract insects and rodents. These will deposit eggs, hairs and excretions that will contaminate the next time the grinder is used. Besides the grinder, the room and the deposits used must be kept clean.

The grinder can be easily cleaned taking off the front burr, the rotating burr, and pulling out the helix. A brush, a piece of hose, and a long, thin piece of metal will help to remove flour left in the grinder. If the burrs were choked up they can be taken out and washed with water, which will soften the material and make cleaning easy. After washing the burrs they must not remain wet because that will cause rust to form. Water must not be used on other parts of the grinder. If grease must be removed, a moist piece of cloth with some soap can be used. See the CTI training manual for details. For a motorized grinder it is not recommended to take out the shaft.

WARNING:

PLEASE REMEMBER TO DISCONNECT THE GRINDER FROM THE POWER SUPPLY BEFORE CLEANING

9. SAFETY MEASURES AND INJURY PREVENTION

As all motorized equipment the grinder presents certain risks of accidents or damage to your health if not used properly or without the required personal protection equipment. Table 9 presents the worst risks and the ways to reduce them.

Before servicing the grinder, the power cord must be unplugged. If something doesn´t function well the grinder must be stopped to find and eliminate the cause. With the basic measures the risks can be reduced and accidents or injury avoided. It is not recommended to leave the grinder running unattended or to allow children to get close to it, even while not running.

Table 10. Risks related to the grinder (with motor)

Part	Risk	Measures
Belt and pulleys	Cuts or loss of fingers or pulling in loose clothes	Belt protectors, No loose clothing
Helix	Cuts of fingers, grasping tools	Not to touch turning helix
Power cord	Electric shock	No cutting or pulling of the cord
Switch	Unexpected start of the motor	Unplug before service, no kids around
Motor	Electric defect	Motor must be grounded
Hot discs	Burns	Use gloves or wait until cooled
Noise	Ear damage	Earplugs, do not run dry
Dust	Lung damage	Discharge funnel, dust mask

10. OTHER ASPECTS TO KEEP IN MIND

- If the hopper is filled with grain and the burrs tight, the burrs can choke up quickly. When that happens the motor will be forced to stop or the belt will fall off and the helix can be deformed. In the beginning the feeding must be limited, and in doing so, coarse flour can be obtained in the first step.
- It is easier to grind dry grains than tempered grains because the humidity makes the material stick to the burrs.
- When the material chokes up the burrs, stop the motor quickly and clean the burrs before trying again.
- In order to remember the position of the burr tightening screw, one point of the ailed screw can be marked. In the case the burrs have to be loosened for a moment, it can be easily put back in its original position.
- The order to start the grinder should be: 1. Start the motor; 2. Put in the material; 3. Tighten up the burrs.
- For optimal grinding, the feed rate and the burrs' tightness should be balanced and adjusted to the material.

- In order to use the full power of the motor an amp meter is recommended.
- New burrs have sharp surface burrs and will be noisier than after a several hours of operation. Burrs that have been used for a long time will be less noisy and will produce finer flour, at lower output.
- A list of common problems and their solutions can be found in the appendix.

11. MAINTENANCE OF THE CTI GRINDERS

In order to keep the grinder running trouble free, some activities have to be carried out regularly.

Activity	Frequency
Clean the grinder after every use and leave it covered.	**Before a period of no use**
Inspect the cord, the plug, and the switch	**Regularly**
Keep the disc tightening screw, the washers, and the shaft end oiled	**Weekly**
Tighten nuts if something gets loose	**When it occurs**
Check the belt tension and tighten if necessary	**Monthly**
Grease the ball bearings	**Yearly**
Blow dust of the motor	**Monthly**

12. REFERENCES

CTI: www.compatibletechnology.org

INTSORMIL: www.intsormil.org

CENTA: www.centa.gob.sv

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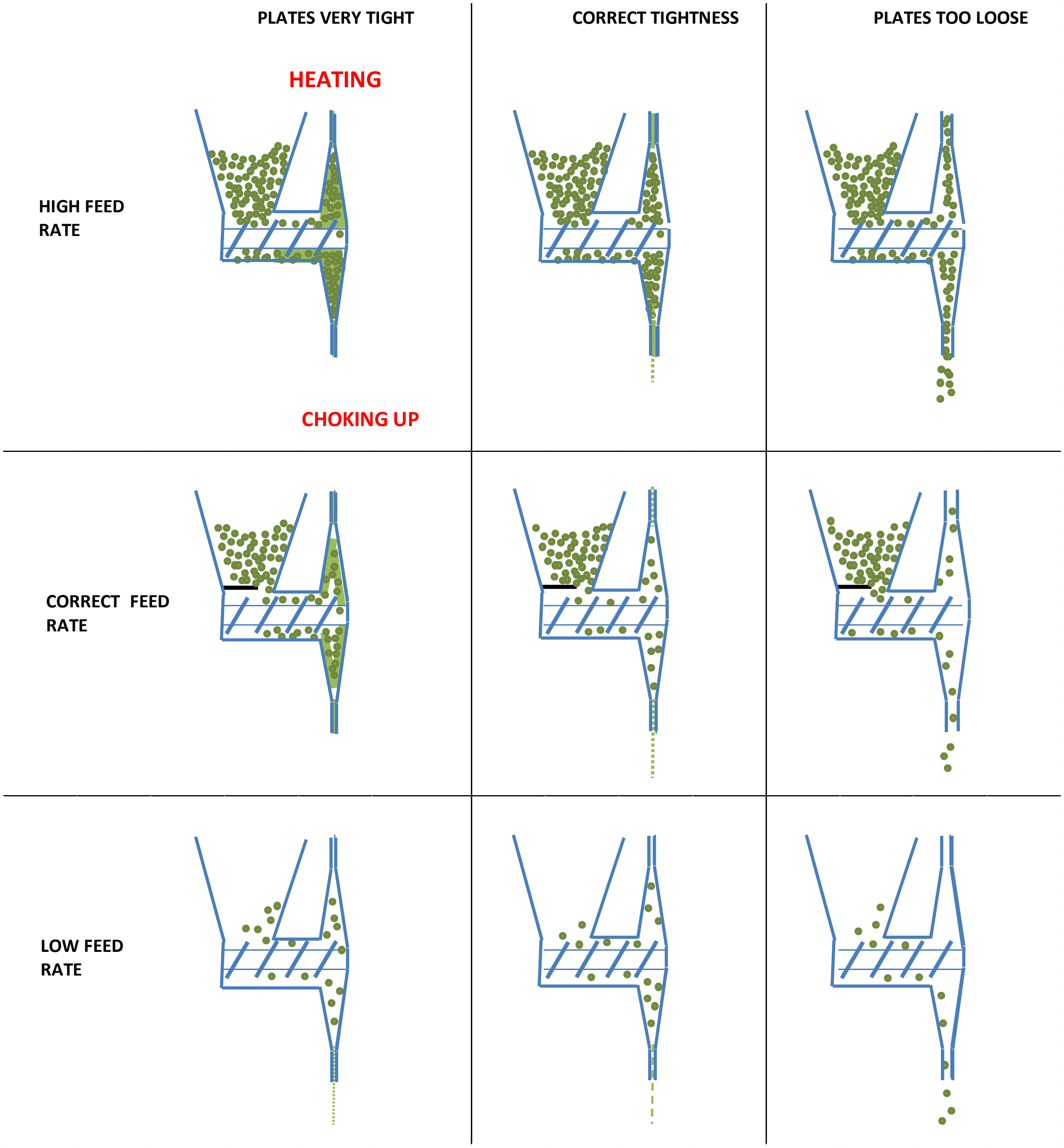
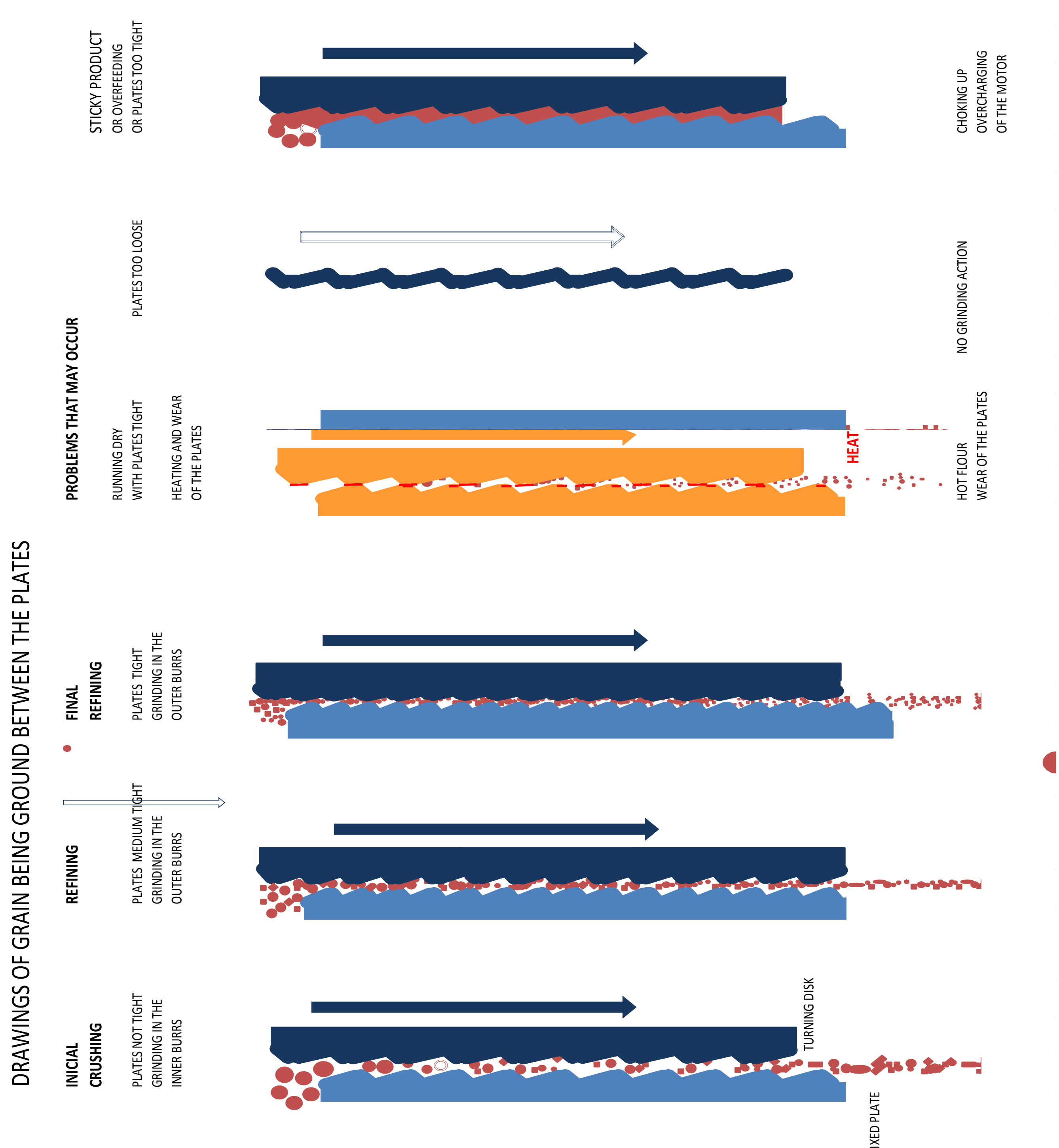
APPENDIX

DRAWINGS OF FEED RATE AND PLATE TIGHTNESS COMBINATIONS



1. **FEED RATE AND PLATE TIGHTNESS COMBINATIONS**

2. DRAWINGS OF THE GRINDING PROCESS



3. UTENSILS USED TO REGULATE THE FEED RATE

MIXED HELIX: Basically it is ¾ of a thin hélix with a piece of thick hélix welded to it to be located at the hoppers side. It moves the product more vigorously and improves the feeding of flour.

HOPPER: An opining at the base permits inspection and pushing down the product when necessary.

PLATE WITH HOLE: To be used in the first step to avoid that too much grain runs into the grinder. It is placed over the auger helix.

BAFFLE IN THE HOPPER: In order to avoid compaction of the flour in the cone. The flour will flow arround it, and stay loose until it the helix moves it in.

SPRING: Of thick galvanized steel wire and a PVC tube stopper that has been cut to let the flour pass through. Agitates the flour and moves it down.

4. UTENSILS USED TO REGULATE THE FLOW FOR EACH GRINDING PASS

FIRST PASS:

Plate with a hole

SECOND PASS:

Plates leaving an opening of about 1 cm

THIRD PASS:

Plates leaving an opening of about 2 cm

Spring agitator

Hopper with baffle

Small plate if mixed hélix is used

SIXTH PASS (for very fine flour):

Spring agitator

Thick or mixed helix

Hopper with baffle

5. PROBLEMS THAT MAY OCCUR DURING GRINDING AND HOW TO SOLVE THEM

PROBLEM	SOLUTION
The burrs get choked up, cuased by :	**Depending on the cause:**
Burrs too tight	Clean burrs and grind less tight
Overfeeding	Feed less, maybe manually. Use thin auger helix.
Sticky material	Dry it or mix it with not sticky material
Burrs filled with material	Clean (best by washing) the burrs
The material doesn´t go down, caused by:	**Depending on the cause :**
The flour is already quite fine and forms a bridge in the hopper	Agitate the material by hand or placing an agitator in the hopper. Or feed by hand, moving the material with a brush.
The auger hélix was not mounted	Mount the auger helix
The flour comes out hot	Loosen the plates a bit
Flour falls out from Omega VI around the shaft	Seal the space between the body and the shaft with silicone (put paper sleeve around the shaft first)
The front burr is moving considerably	The burrs are almost choking up. Loosen them a bit.
A sharp noise from the burrs caused by:	**Depending on the cause:**
Grinding burrs are new	Use them, they will wear out a bit and adjust themselves
Grinding burrs running dry (without material)	Assure proper feeding of the material
Unusual noise	**Depending on the cause:**
Some part is not tight	Check and tighten screws
Some undesirable object got stuck	Stop inmediately, open the discs and remove object.

6. DEFECTS OF THE EQUIPMENT

FAULT	HOW TO FIX IT
The motor runs but the belt doesn´t move	The pulley may be loose or the belt not tensioned. Find and tighten the loose part.
The belt moves but the grinder not	The pulley of the grinder is loose. Tighten its screws.
Black metal powder falls from the Omega VI body at the hole where the shaft enters the body.	The shaft is scraping the body. Loosen the bolts of the bearings and position them so that the shaft does not touch the body. Tighten them well.

Electrical defects

FAULT	HOW TO FIX IT
The motor doesn´t start	Check the energy supply, the cord or switch and repair
The motor attempts to start but isn´t able to, making a humming sound or moving slowly.	Switch off immediately. Most probably the burrs are too tight or choked up. Loosen and/or clean them. If not, a motor part failed. Have it fixed. **DO NOT OPERATE THE MOTOR IF IT DOESN´T WORK WELL**
The motor started and shut off by itself	Probably the thermal protectión jumped off. Find out the cause and correct it.
The motor heats up more than normal	If overcharged loosen the burrs, otherwise the power supply may be deficient. Find the cause and have it fixed. (don´t use additional power cords)
The motor runs but interrupted	Probably there is some bad contact somewhere. Have it fixed.
The motor smells burnt or some part exploded	The motor failed. Have it repaired or changed
Static electricity is felt from the grinder´s body in case of a wooden stand	This happens when the belt slips. Tighten the belt. Ground the body with a metal wire to the motor body.