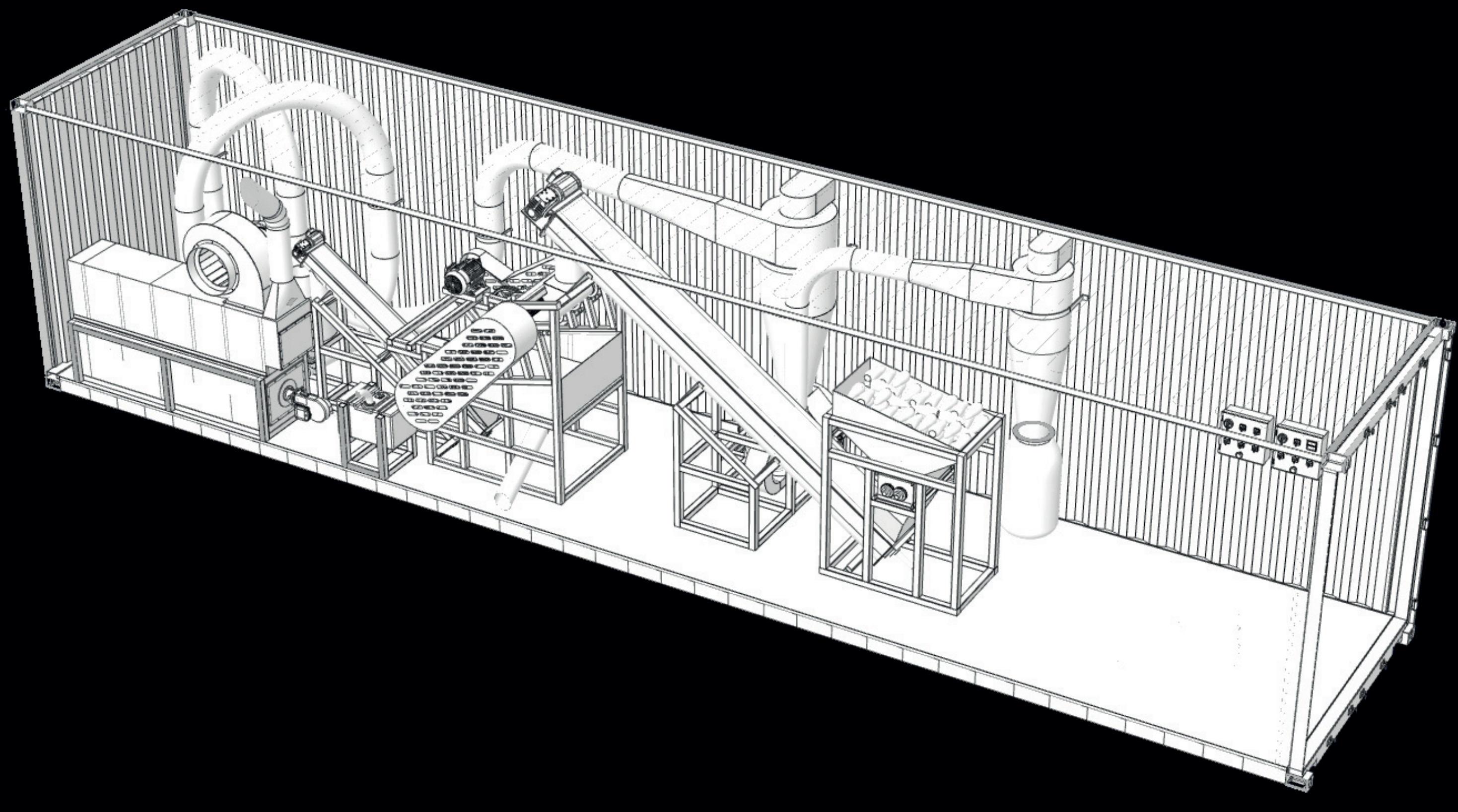
Continuous flow cassava flour factory

Construction guide delivered to KARDI DRYERS LTD., in fulfilment of the project *Design and construction of a novel, small-scale, cassava starch factory* funded by HEIF



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Introduction

Cassava (*Manihot esculenta* Crantz) is a tropical root with strategic importance to sub-Saharan Africa, as it is the main source of calories for a considerable proportion of its population. Cassava has a short shelf life and for human consumption needs to be processed into flour within 48 hours after harvest. For this reason, cassava processing plays a key role in food security. To produce cassava flour, they are peeled, grated, pressed, pulverized, dried, and milled. This document supplies guidelines for the construction of an innovative cassava processing centre; one that operates in a continuous flow process and that is fitted inside a shipping container, delivered to the user ready for operation.

Factory overview

The entire factory is fitted inside a high cube intermodal shipping container (Figure 1) and includes one *roll crusher*, two *screw conveyors*, one *roller press*, one *pneumatic dryer* and one *hammermill* (Figure 2). The factory can process 13,200 kg of fresh cassava roots per day (550 kg/h) resulting in an output of 3,600 kg of cassava flour per day (150 kg/h).

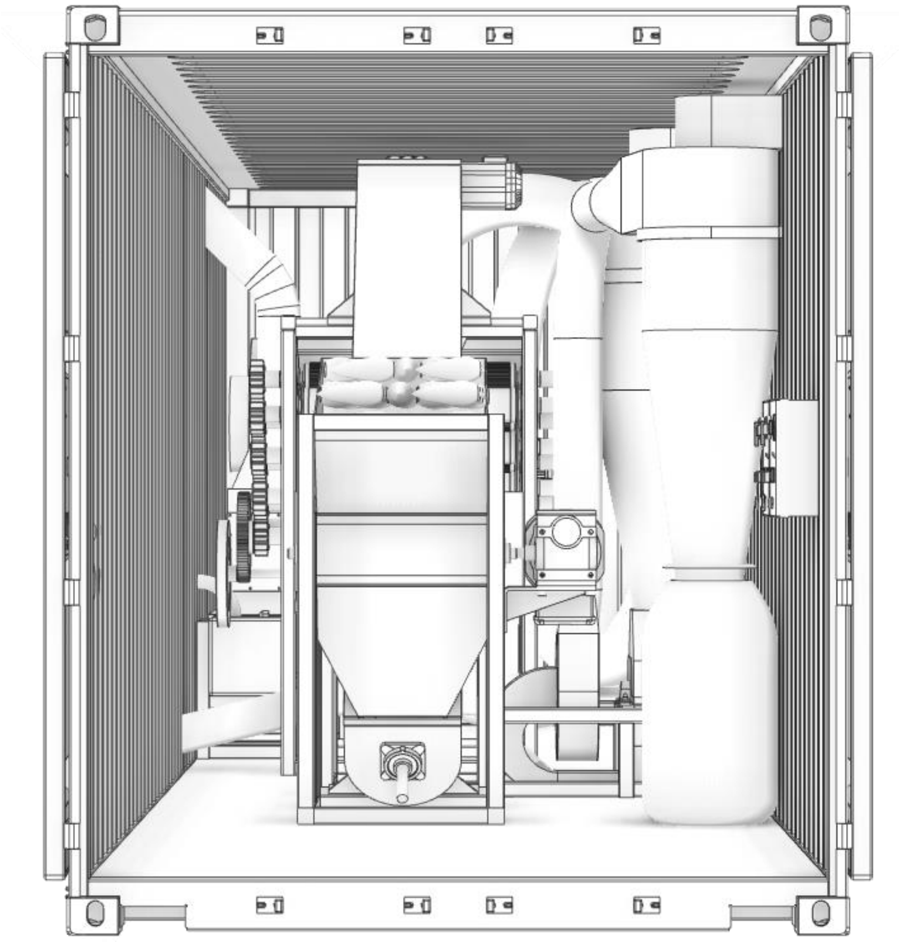


Figure 1. Cassava flour factory inside a container shipped ready for operation.

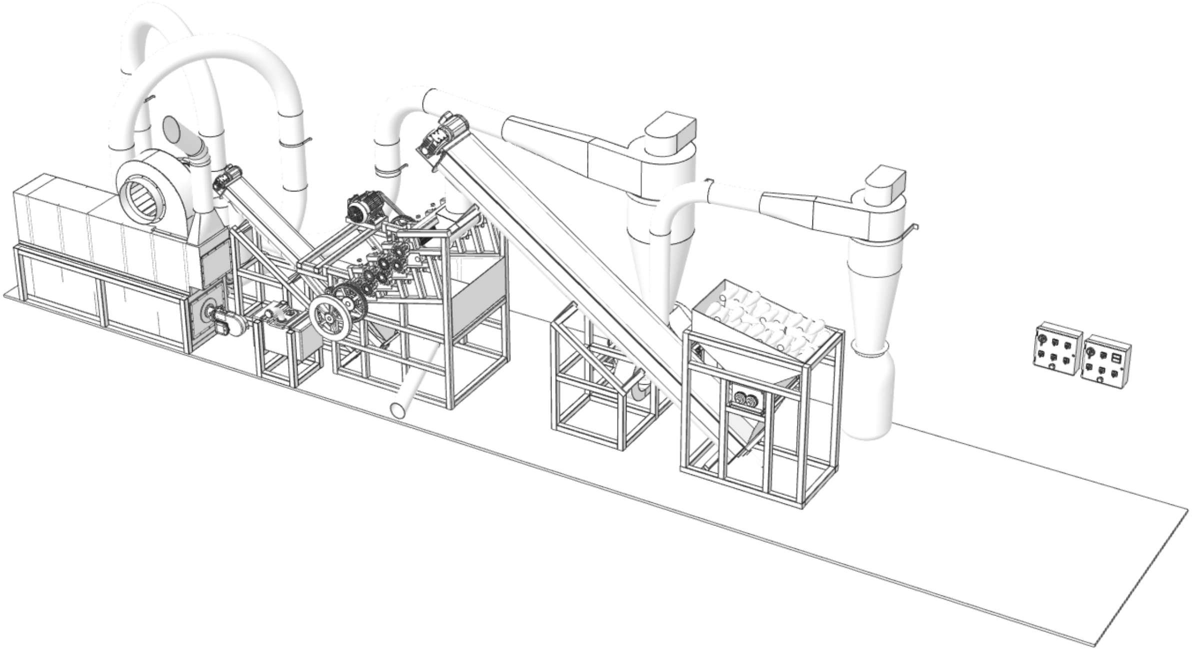


Figure 2. Equipment inside the container of the cassava flour factory.

Factory components

High cube intermodal shipping container

The factory is fitted inside a standard high cube general-purpose container, 40 feet (12.19 m) long and 9 feet 6 inches (2.90 m) high. The only modifications made to the container are the openings on both walls for air exhaust and water drainage (Figure 3).

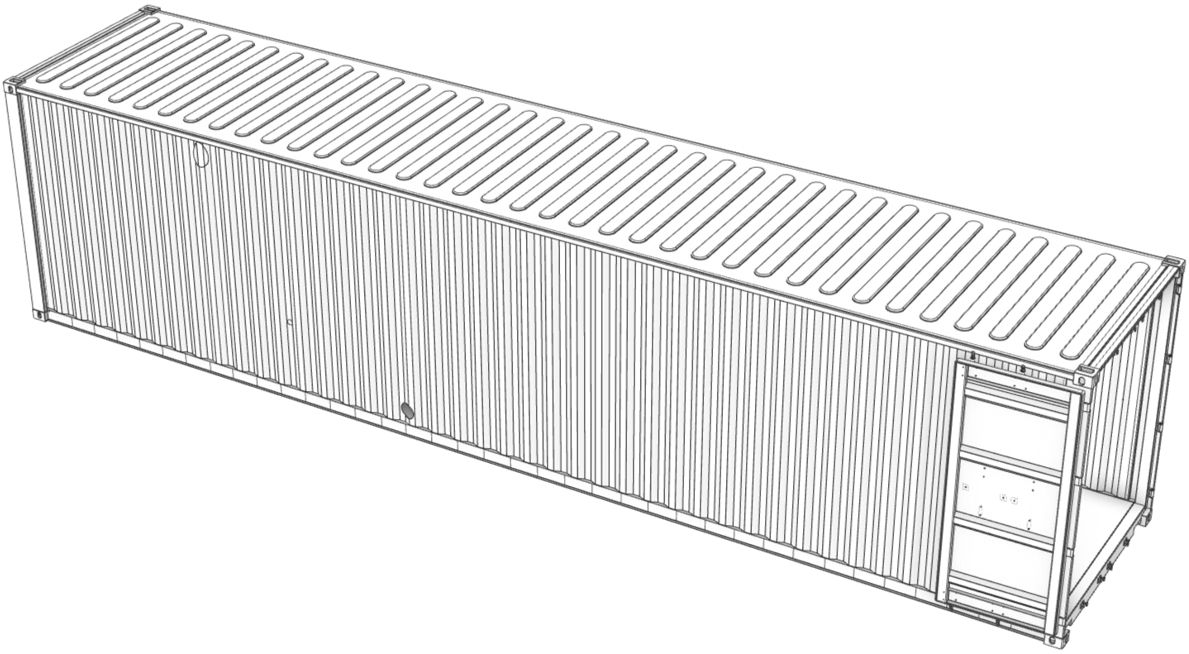


Figure 3. A standard high cube 40 feet container houses the factory.

Crusher

The first piece of equipment of the cassava flour production line is a roll crusher, where the peeled and washed cassava roots are placed to be grated. The equipment consists of two counter-rotating rolls. The crusher is powered by a single-drive train using a 4-hp Gearmotor with a rotational speed of 160 rpm (Figure 4). Peeling and washing of the roots are done manually outside the factory.

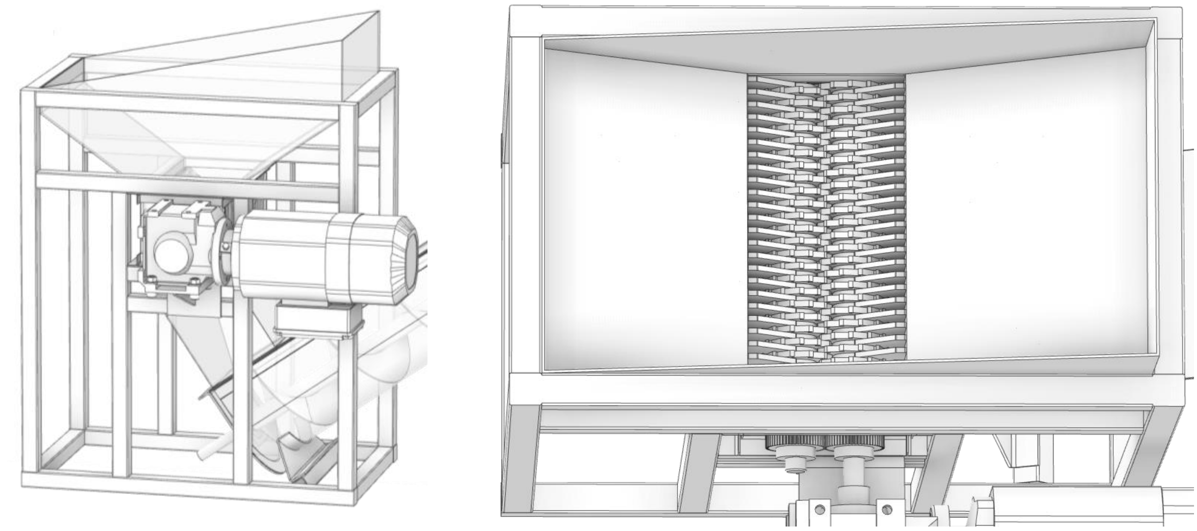


Figure 4. Crusher grates the peeled and washed cassava.

Screw conveyor 1

The crusher discharges the grated cassava directly to a screw conveyor that transports the product to a roller press (Figure 5). The screw rotates at 60 rpm and is powered by a 2 hp Gearmotor.

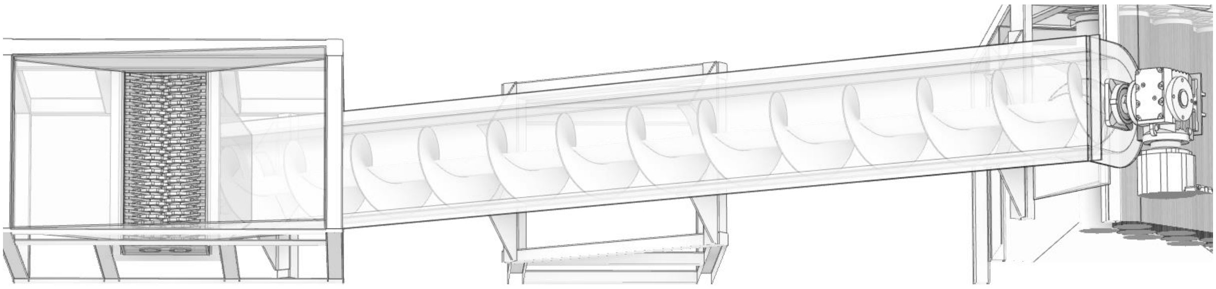


Figure 5. A screw conveyor transports the grated cassava to a roller press.

Roller press

In the roller press, the grated cassava is fed between heavy fluted metal rollers, which squeeze the material, and the water is forced out, flowing along the grooves. Spur gears at the end of the rollers make them rotate. Bushings are used for the interfaces between the shaft and the frame, allowing the shaft to rotate and at the same time allowing to adjust the distance between the rollers by sliding the bushes along the frame. Bolts fixed to the frame with nuts are used to adjust the position of the bushings and thus control the distance between the rollers. Below the rollers, a collecting plate gathers the water and guides it to the outside of the container. The dewatered material is discharged into a screw conveyor. The system uses a 5 hp motor with a high-speed clockwise rotation. Power from the motor is transferred to a driven shaft using a belt and pulley system. At the oposity extremity of the driven shaft, a flywheel is used to store the rotational energy. (Figure 6).

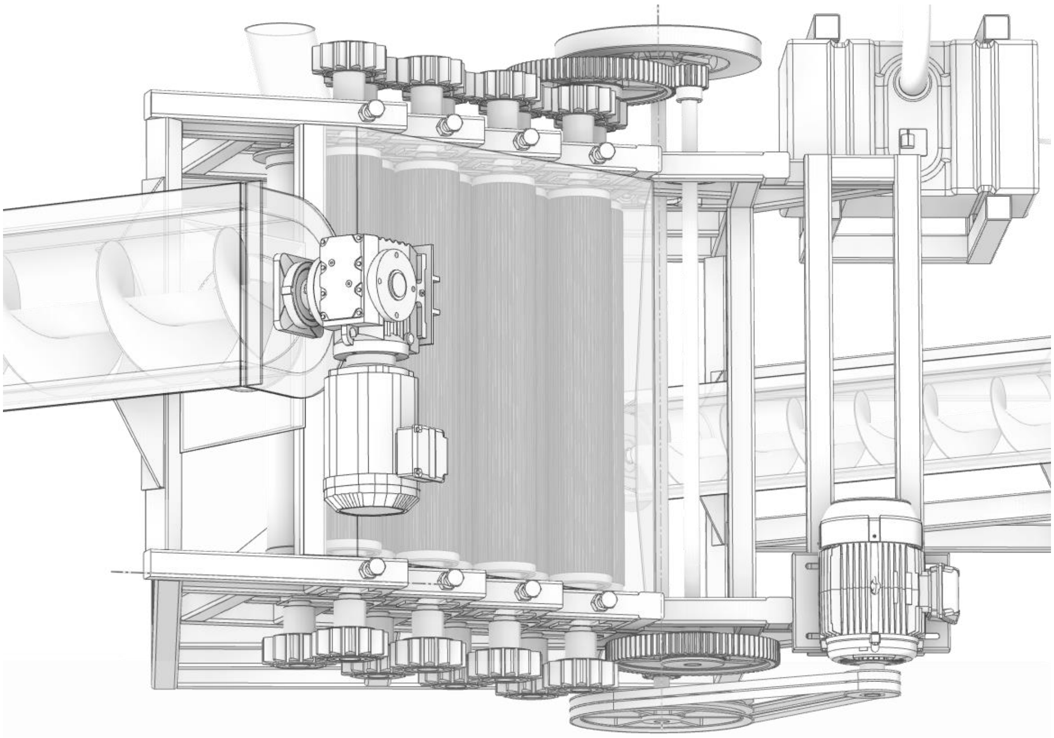


Figure 6. A roller press is used to mechanically dewater the grated cassava.

Screw conveyor 2

A screw conveyor transports the dewatered material to the dryer's feeder. The screw rotates at 60 rpm, powered by a 1 hp Gearmotor (Figure 7).

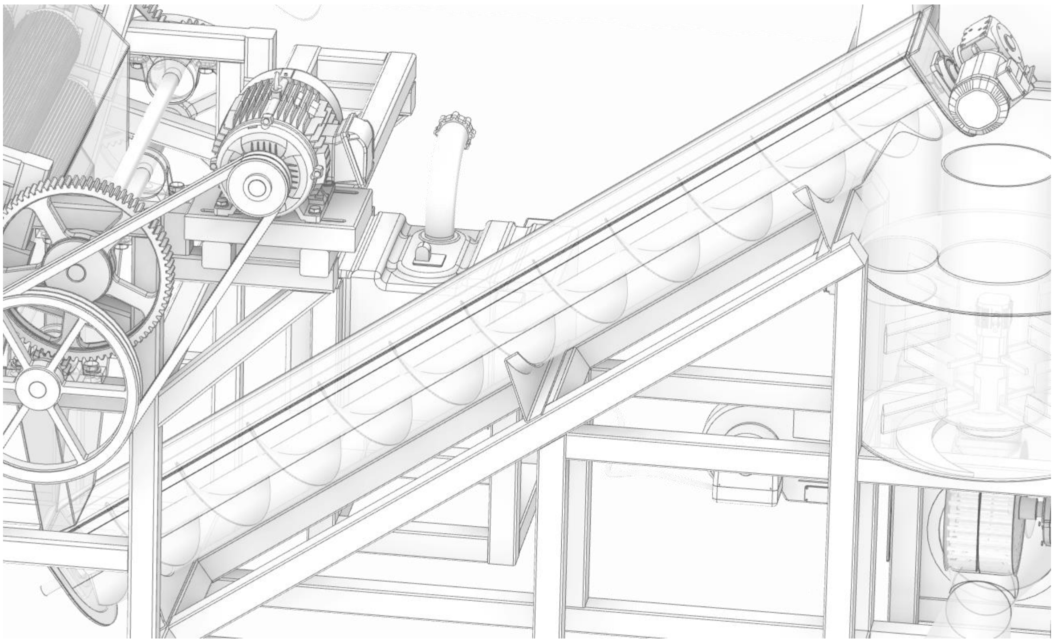


Figure 7. A screw conveyor transports the dewatered material to the dryer.

Pneumatic dryer

The pneumatic dryers are composed of a feeding system, a drying duct, a cyclone, a heating unit, and a fan. The equipment was dimensioned to dry cassava from a moisture content of 45% on a wet basis (wb) to a moisture content of 12%wb. The throughput of the dryer was designed to deliver 150 kg of dried product per hour. Because of the correct dimensioning of this dryer, it is expected energy efficiency of 60%, meaning that to produce 1 kilogram of dried product 0.1 litres of diesel will be consumed. Figure 8 provides an overview of the dryer.

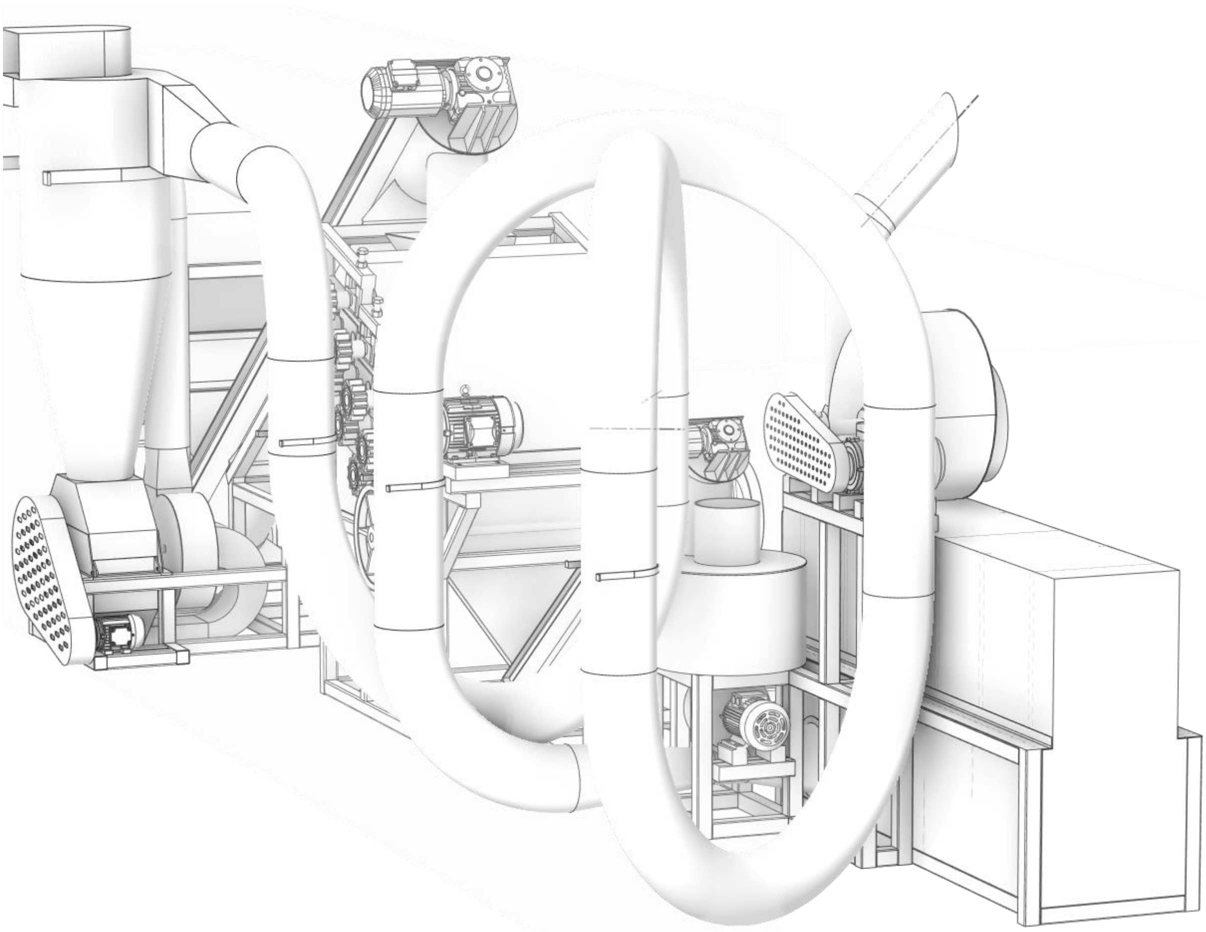


Figure 8. Overview of the pneumatic dryer fitted inside the container.

Feeding system

In pneumatic dryers, the material should be introduced to the drying duct at a controlled, specified rate, and should be well dispersed with the airstream. Wet cassava grits have poor flow properties, and to avoid material bridging or ratholing, the hopper should have vertical walls. The material outlet of this feeder is a central orifice in the bottom of the hopper. Directly above this orifice, a cylinder lodges the motor and gearbox that moves the flow aid device. The flow aid device has a curved shape and as it rotates, moves the material to the outlet. The rotational speed of the flow aid device ranges from 14 rpm to 40 rpm and is powered by a Gearmotor of 1 hp. However, calibration must be performed to find the exact rotational speed that feeds 245 kg/h to the dryer. Appendix 1 explains the calibration procedure.

Because pneumatic dryers must be fed with non-lumpy material, after the feeder, a disintegrator must be present to break any agglomerated material developed, assuring a steady stream of finely divided solid that disperses evenly into the airstream. The disintegrator is powered by a 1 hp motor. In addition, to assure a negative pressure and a sucking force, the drying duct has a venturi shape at this feeding point. Figure 9 provides an overview.

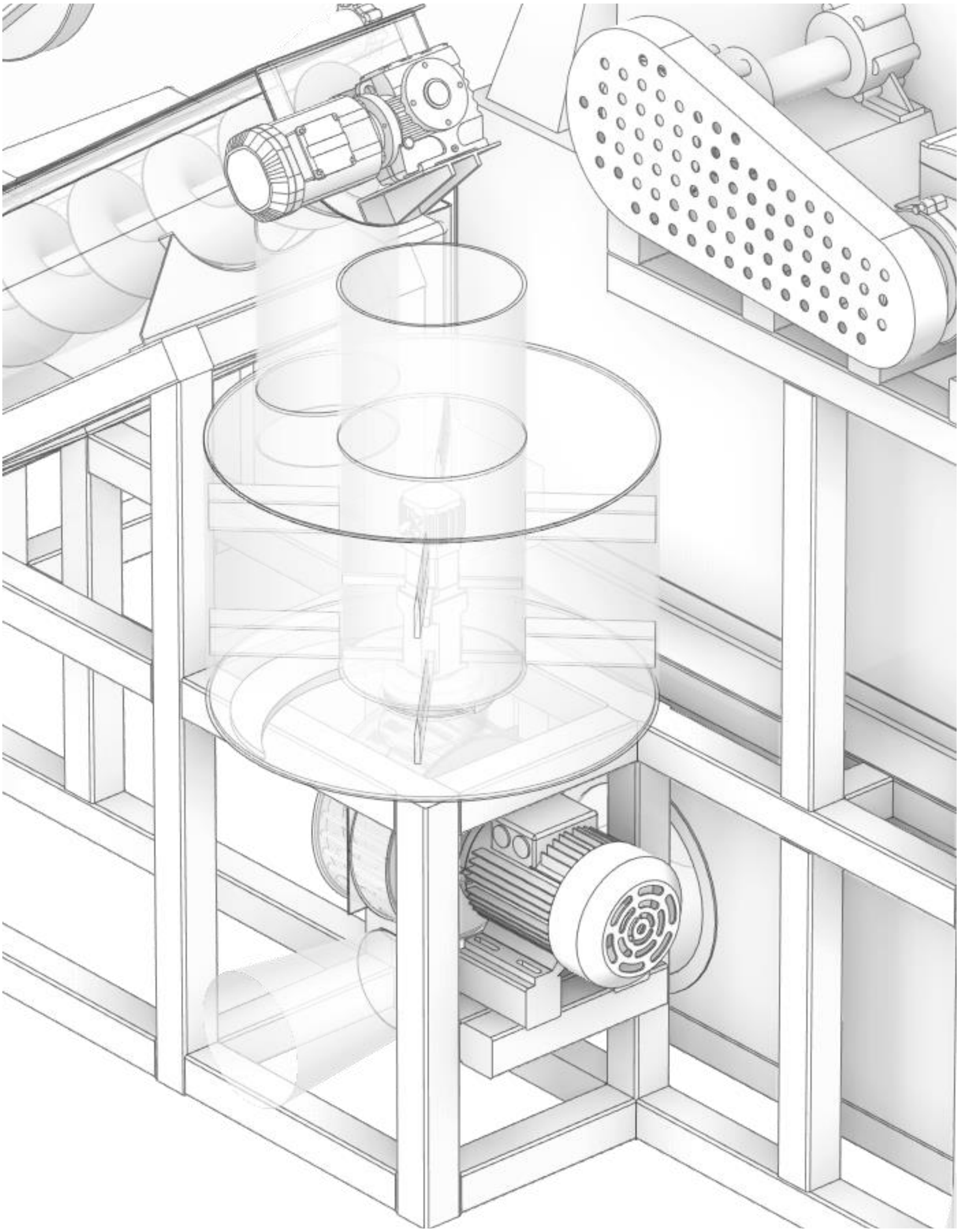


Figure 9. The feeding system uses a hopper with a vertical wall and a disintegrator.

Drying duct

In pneumatic dryers, the drying duct must be long enough to provide the required residence time for the material to reach the target moisture content. In addition, the drying duct must be thermally insulated to reduce heat losses. Figure 10 provides an overview of the drying duct.

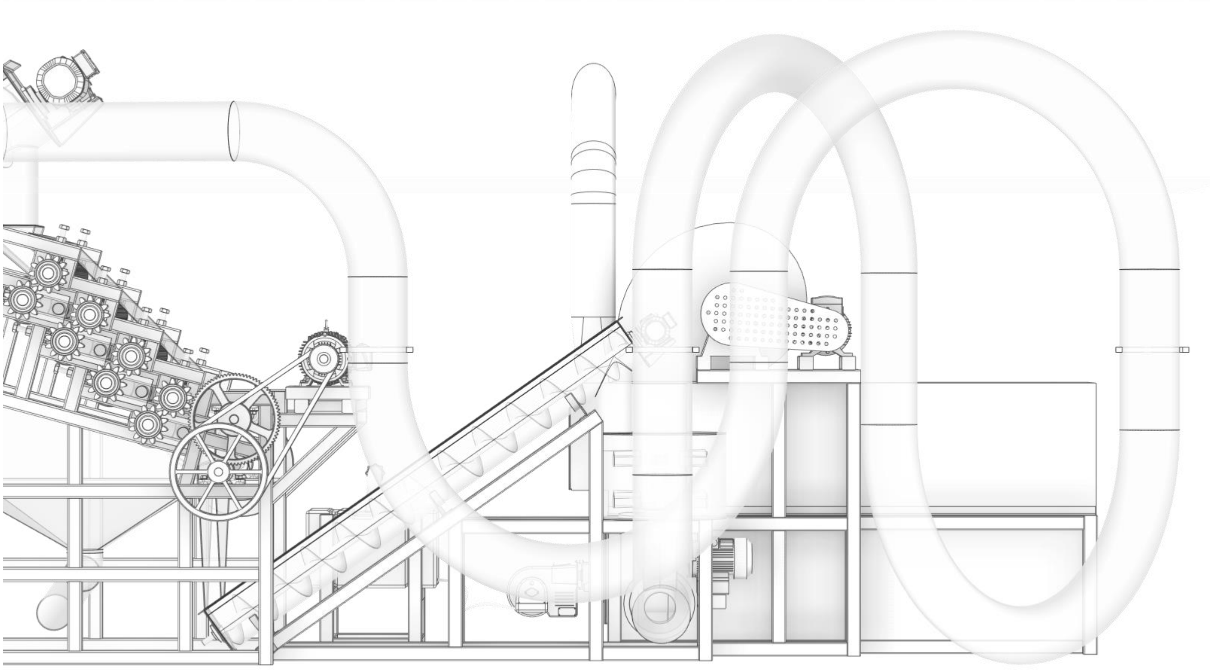


Figure 10. The drying duct has meandering sections to fit inside the container.

Cyclone

At the end of the drying duct, a cyclone separates the dried solid from the airstream. The dried cassava grits leave the cyclone from its bottom, and the air exits from its top. The cyclone was dimensioned using the Peterson-Whitby design (Figure 11).

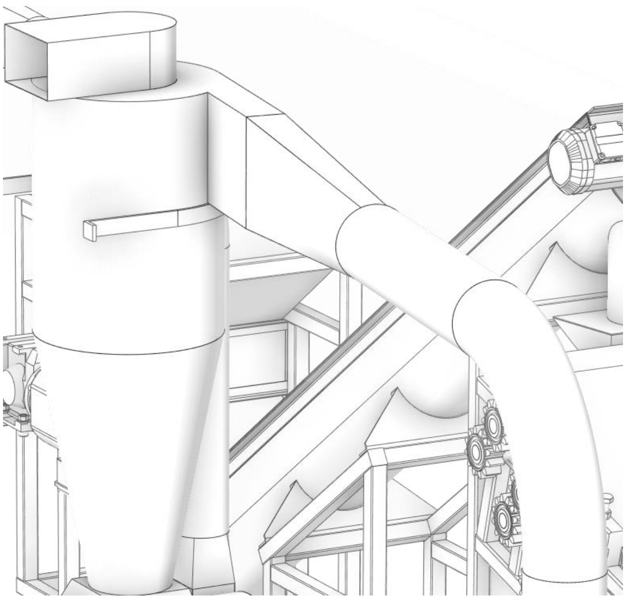


Figure 11. The cyclone at the end of the drying duct separates solids and airstream.

Heating unit

The heating unit has the function of warm-up the air. The unit consists of a burner, a combustion chamber, and a shell-and-tube heat exchanger that contains a bundle of parallel tubes enclosed in a shell (Figure 12). A turbulator, placed inside each of the tubes, increases the heat transfer surface further. The burner to be used with this heating unit should have a power of 130 kW. An example of a suitable burner is the Bairan model B14 or Riello model 40G. The burner must be thermostatically controlled, and the temperature sensor should be placed at the dryer's cyclone air outlet.

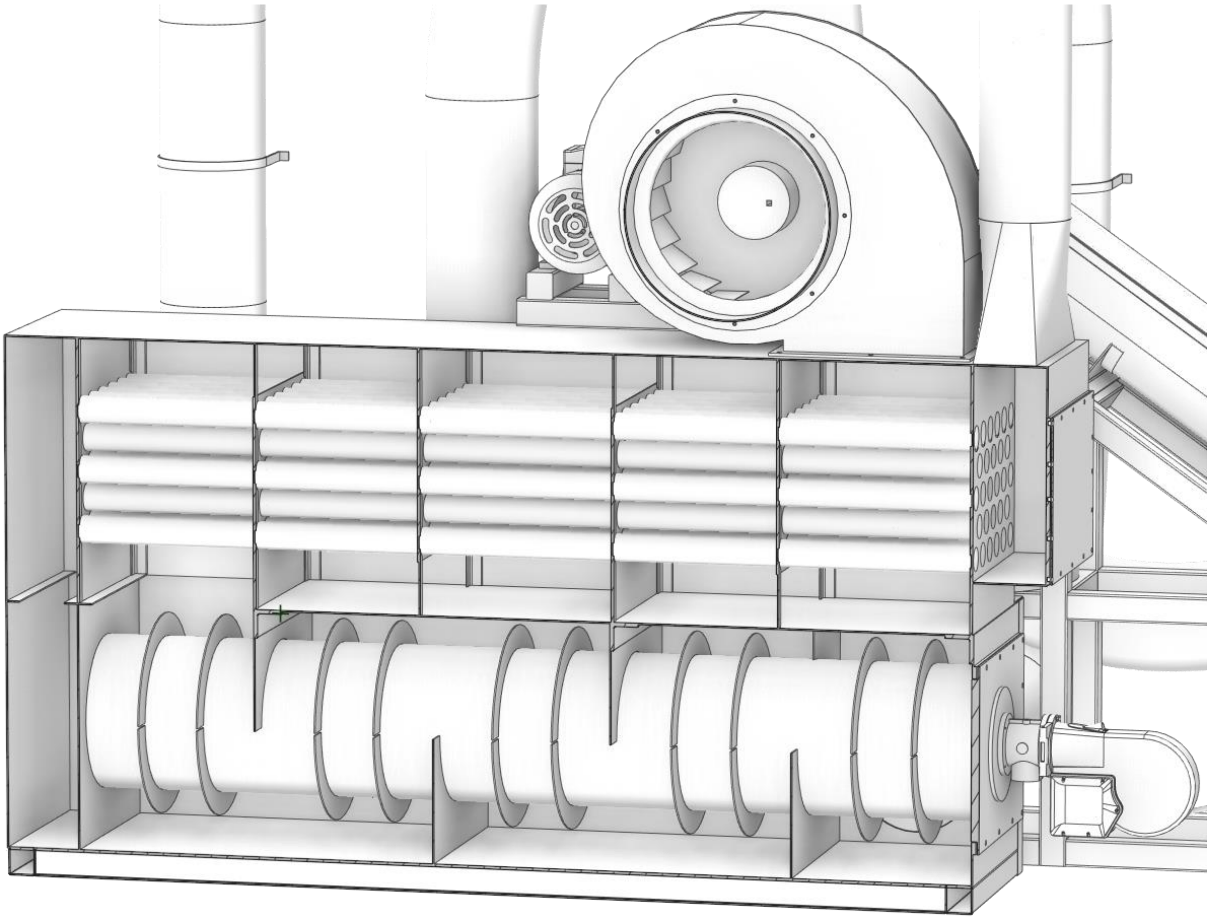


Figure 12. Cross-section view of the shell-and-tube heat exchanger.

Fan

The fan has the function to induce air. The designed fan is a centrifugal blower with a squirrel-cage impeller. It should be powered by a 5 hp electric motor, using V-belt transmission. The impeller should have a speed of approximately 950 rpm, but the exact rpm, and consequently the pulleys' sizes, need to be determined by trial and error, using an anemometer to measure the air velocity (see Appendix 2 for a detailed explanation on the procedure).

Hammermill

From the dryer's cyclone, the dried product is discharged directly into a hammermill. The equipment is composed of a case, rotor, rods, hammers, sieve, fan, and cyclone. Inside the case, the rotor and the rods spin at high speeds and in their periphery, the hammers are attached and swing in a circular path. The hammers hit the product entering the housing, reducing its size by impact. The product leaves the housing when is small enough to pass through the sieve at the bottom. Particle size is adjusted by changing the orifice size of this screen; one with larger openings results in larger particles. Because the product is dried, and therefore light, a fan is used to generate forced air, which conveys the product (Figure 12). A cyclone separates the material from the conveying air. The hammer mill is powered by a 5 hp electrical motor using a belt and pulley transmission with a flywheel to store rotational energy.

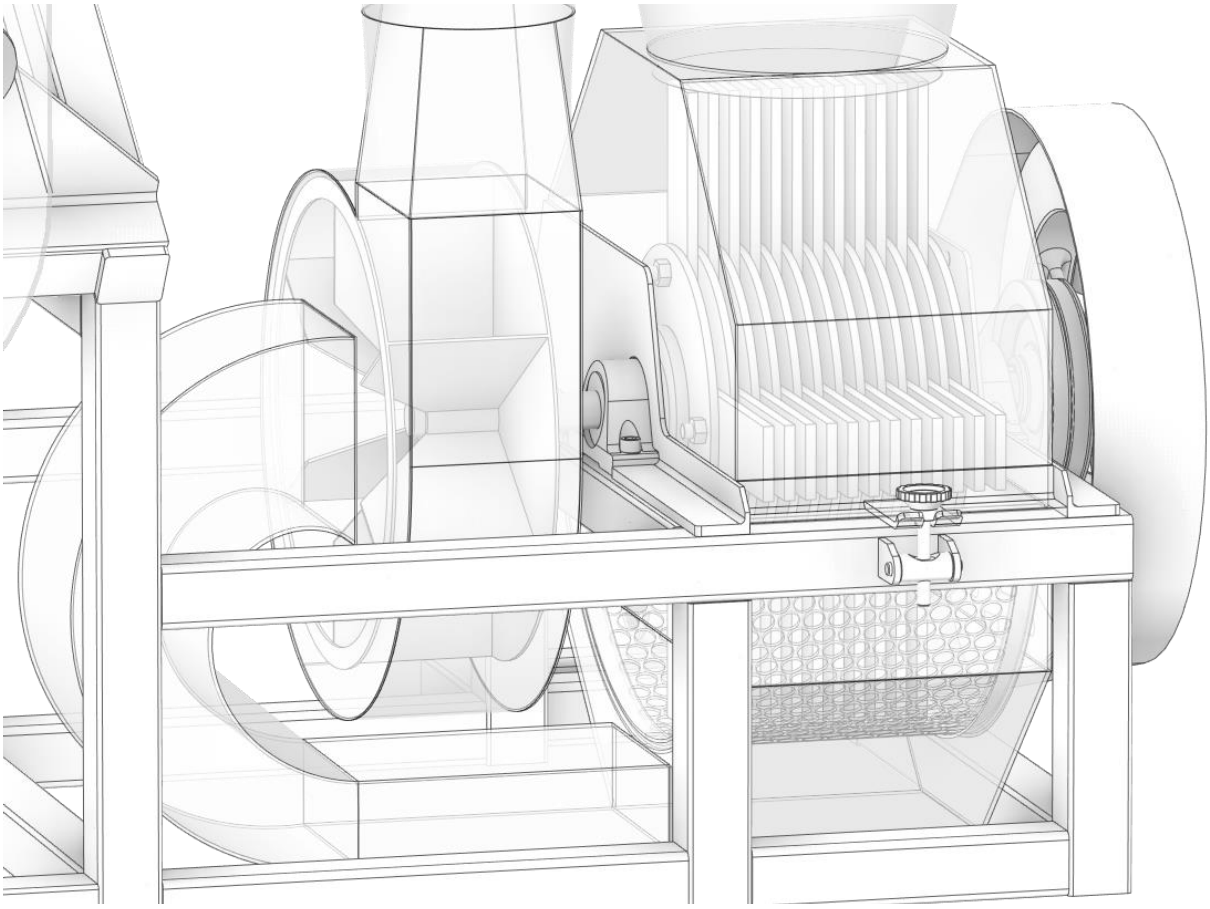


Figure 12. A hammer mill grinds the dried product into flour.

Equipment Dimensions

Dimensions of the equipment and the 3D CAD model can be visualized or downloaded from https://autode.sk/3aWUFbc or from https://a360.co/3ztKnce (both password protected). All parts that come in direct contact with cassava material must be built with food-grade stainless steel. Parts that do not come in contact with the cassava material do not need to be made of stainless steel but must be coated with corrosion-resistant paint. In addition, all belt drive components and spur gears must be enclosed under a safety guard.

APPENDIX 1: HOW TO CALIBRATE FEEDING RATE

The dryer was designed to be fed with 245 kg of wet cassava grits per hour. The dryer will still work, and the target moisture content might still be reached, if more than 245 kg/h of wet solid is fed to it, however, its efficiency will decline substantially, as the dryer will operate out of its design point. Similarly, the dryer will still work, and the target moisture content might still be reached if less than 245 kg/h of material is fed. However, again, efficiency will decline. Therefore, it is important to perform this calibration and assure a steady feeding rate of 245 kg/h. The feeding rate is controlled by the rotational speed of the flow aid device. Higher the speed, the higher the feeding rate.

MATERIAL NEEDED

- 490 kg of wet cassava grits with a moisture content of 45%wb
- 10 bags (sacks)
- Weight scale
- Stopwatch

PROCEDURE

Step 1. Divide the 490 kg of wet cassava grits into 10 bags, using the weight scale to make sure that each bag contains 49 kg of product.

Step 2. Switch the entire dryer system on and waits until it warms up.

Step 3. Once a steady state has been reached, add an entire bag (49 kg) to the feeder, and at the same time start the chronometer of the stopwatch.

Step 4. At the moment that the material finishes and the feeder becomes empty, stop the chronometer, and note down the time elapsed.

Step 5. If the time elapsed was longer than 12 minutes, increase the rotational speed of the flow aid device. If the time elapsed was shorter than 12 minutes, decrease the rotational speed of the flow aid device.

Step 6. Repeat this procedure until the rotational speed that makes the feeder empty in 12 minutes is found. This is the rpm that supplies a feeding rate of 245 kg/h. Operate the dryer always at this feeding rate and do not make further changes to the rotational speed of the flow aid device.

APPENDIX 2: HOW TO ADJUST AIR VELOCITY

The speed that the fan impeller rotates determines the amount of air passing through the dryer, and the air velocity inside the drying duct. The amount of air passing through the dryer and the air velocity inside the drying duct has a significant impact on the dryer operation and its efficiency. Therefore, it needs to be correctly and precisely adjusted. The dryer will still work with the incorrect air velocity, but its energy efficiency and the quality of the product will be significantly jeopardised. The speed of the fan impeller is adjusted by changing the sizes of the pulleys of the drive system. A variable frequency drive is not needed because, once the correct rotational speed has been identified, it will not need to be changed again.

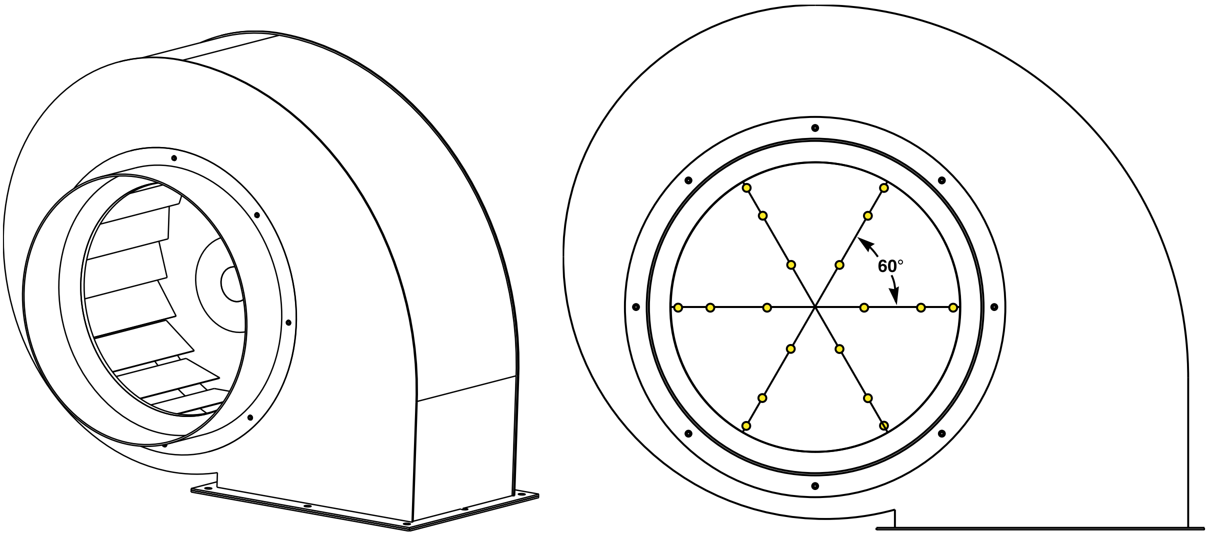
MATERIAL NEEDED

Anemometer (device to measure air velocity)

PROCEDURE

Step 1. Switch the fan on.

Step 2. At the fan inlet (air intake) perform 18 air velocity measurements over the cross-sectional area as shown below:



Step 3. Note down the 18 measurements and calculate the average.

Step 4. If the average air velocity is lower than 2.5 m/s, increase the rotational speed of the fan impeller by reducing the size of the driven pulley. If the average air velocity is higher than 2.5 m/s, reduce the rotational speed of the impeller by increasing the size of the driven pulley.

Step 5. Once the average air velocity at the fan inlet is 2.5 m/s, the correct air amount of air passing through the dryer and the correct air velocity inside the drying duct have been achieved, and no further change in the rotational speed of the impeller should be made.

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