RTB Working Paper

Feeding system for cassava pneumatic drying

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INTRODUCTION

In a dryer, a feeding system is the devices that introduce material into the equipment at a controlled, specified rate. Feeding systems have two main components, a hopper, also known as bin, and a feeder. The hopper has the function to store the material, temporarily, before being discharged. The feeder has the function to control the discharge rate.

For pneumatic dryers, feeding systems have some specificities. The feeding rate should be continuous and very uniform, plus the material should be added to the airstream in a free-flowing form, without lumps. For this reason, the hopper of a feeding system for pneumatic dryer should be designed in a way where no arcing, also known as bridging (Figure 1a), ratholing (Figure 1b) or any other kind of material stagnation, also known as dead zones, occurs.

(a) (b)

Figure 1. A hopper of a feeding system for pneumatic dryer should be designed in a way that no (a) arcing nor (b) rathole occurs.

Regarding the feeder of a pneumatic dryers feeding system, it should be designed in a way that the control over the feeding rate, also known as discharge flow rate, is accurate and controllable. Moreover, the introduced material must be well dispersed to the airstream. Screw feeders (Figure 2a) and rotary valve feeders (Figure 2b) are commonly used and suitable for pneumatic dryers.

(a) (b)

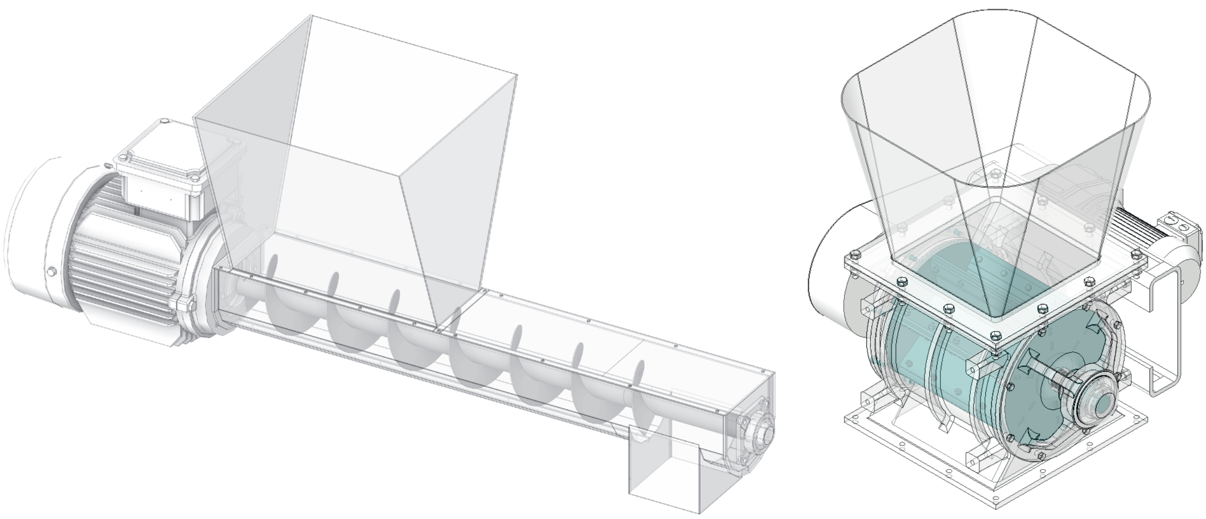


Figure 2. For pneumatic dryers (a) screw feeders and (b) rotary valve feeders are commonly used.

When drying cassava in a pneumatic dryer, the material introduced to the feedings system is wet cassava grits. Wet cassava grits are produced by peeling, washing, and grating the cassava roots. The resulting mash is subsequently mechanically dewatered, and the obtained press-cake is pulverized into wet cassava grits. Wet cassava grits have poor flow properties, it does not flow easily and, instead, it consolidates. The poor flowability of wet cassava grits is attributed mainly to the adhesive forces between individual particles. Those forces are largely caused by liquid bridges. In addition to the poor flowability, wet cassava grits are highly cohesive, meaning that the material is sticky and has the tendency to agglomerate into lumps.

For cohesive material with poor flowability, like wet cassava grits, arching, rathole and other types of material stagnation can occur even in a hopper with vertical walls. To avoid them a hopper for such material should be equipped with a flow aid device, like the one shown in Figure 3.

Figure 3. Flow aid device at a hopper with vertical walls.

Regarding the feeder, rotary valve feeders are not compatible with cohesive material with poor flowability and therefore cannot be used in a pneumatic dryer used to process cassava.

Because pneumatic dryers must be fed with non-lumpy material, after the screw feeder, a disintegrator must be present to break any agglomerated material developed in the hooper or the feeder. In this way, the disintegrator assures a steady stream of finely divided solid that disperses evenly into the airstream.

In sum, based on the properties of wet cassava grits and the requirements of pneumatic dryer feeding specifications, the hopper should have vertical walls, equipped with a flow aid device, and the feeder should use a screw mechanism equipped with a disintegrator (Figure 4). However, the optimum design of the flow aid device, the optimum type of the screw and the optimum model of the disintegrator has not yet been determined for wet cassava grits. Therefore, the objective of this work was to determine the most suitable design of those devices for this particularly cohesive material with poor flowability.

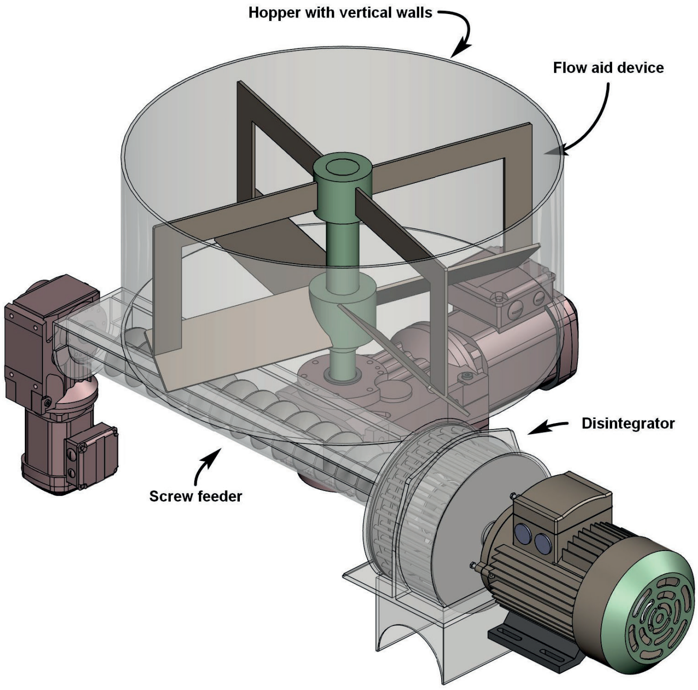


Figure 4. A feeding system for cassava pneumatic drying should have a hopper with vertical walls, a flow aid device, a screw feeder, and a disintegrator.

MATERIALS AND METHODS

FEEDING SYSTEM COMPONENTS EVALUATION

To determine the most suitable design of the components of the feeding system, the software Rocky DEM was used. Rocky DEM is a 3D Discrete Element Method (DEM) modelling program that simulates how particles interact with each other and the surrounding boundaries, allowing to predict its behaviour and calculate power requirements.

FLOW AID DEVICE

Eight different designs of flow aid device were evaluated, as shown in Figure 5.

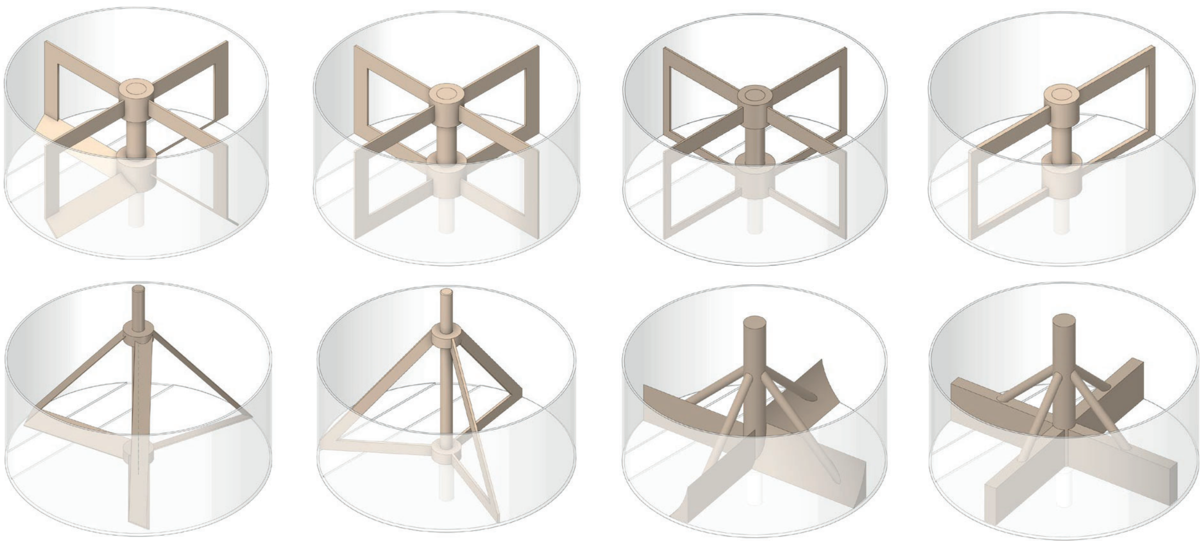


Figure 5. Flow aid devices evaluated using Discrete Element Method (DEM) to determine the most suitable for handling wet cassava girts.

SCREW

Five different designs of screws were evaluated, a standard screw (Figure 6a), a variable pitch screw (Figure 6b), a variable trough screw (Figure 6c), a cut flight screw (Figure 6d) and a cut-and-fold flight screw (Figure 6D).

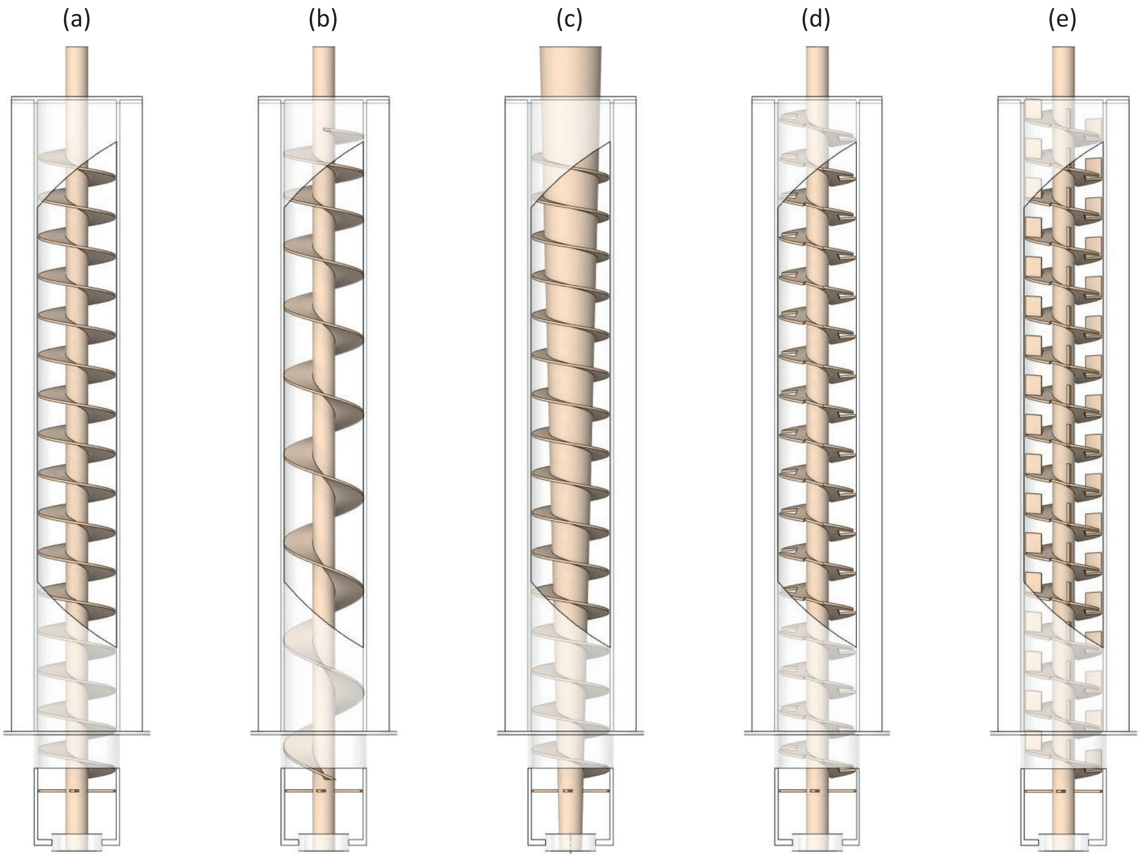


Figure 6. Screws evaluated using Discrete Element Method (DEM) to determine the most suitable for handling wet cassava grits.

DISINTEGRATOR

Three kinds of disintegrator were evaluated, a cage-mill (Figure 7a), a paddle-mill (Figure 7b) and a fan-mill (Figure 7c).

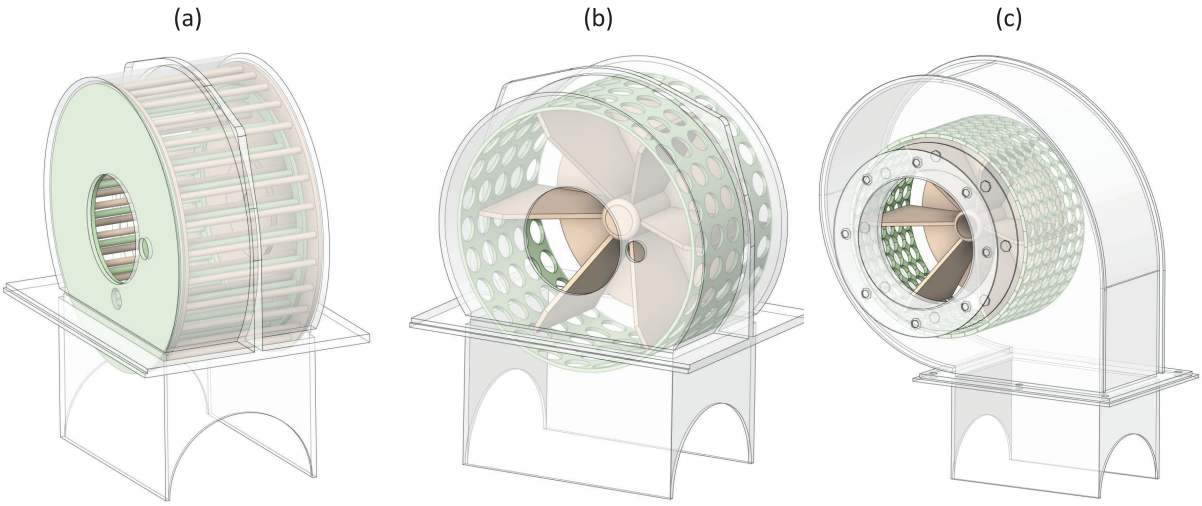


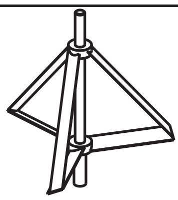
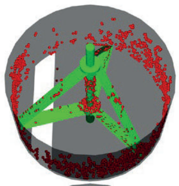
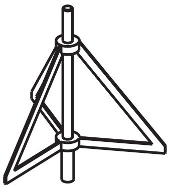
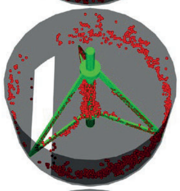
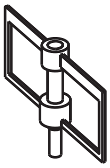
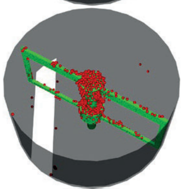
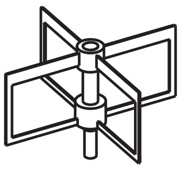
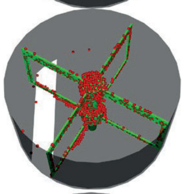
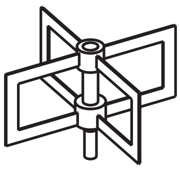
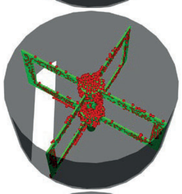
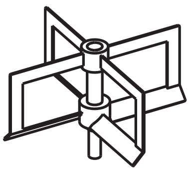
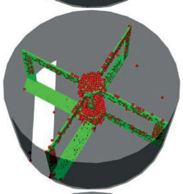
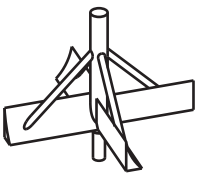
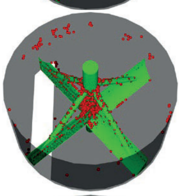
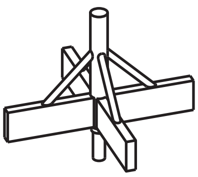
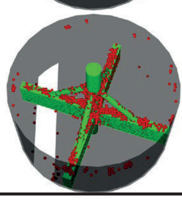
Figure 7. Types of disintegrator evaluated using Discrete Element Method (DEM) to determine the most suitable for handling wet cassava grits.

RESULTS AND DISCUSSION

FLOW AID DEVICE

For wet cassava grits, the flow aid device should have a maximum rotation speed of 14 rpm. Therefore, a correct combination of motor speed and gearbox-reduction-ratio should be employed, though variable speed is not needed. Table 1 shows the results obtained from the evaluation using DEM.

Table 1. Results from DEM simulation showing the stagnant zones and power requirements for different designs of flow aid devices.

Flow aid device	DEM simulation (stagnant zones)	The material in stagnant zones (kg)	Motor power requirement (kW)
		0.8	0.1
		0.8	0.2
		0.9	0.2
		0.9	0.2
		1.0	0.3
		1.0	0.2
		1.7	0.2
		2.7	0.3

As shown in Table 1, the flow aid device depictured in Figure 8 is the one that develops the least amount of material stagnation combined with the lowest power requirement, thus the most suitable for handling wet cassava grits.

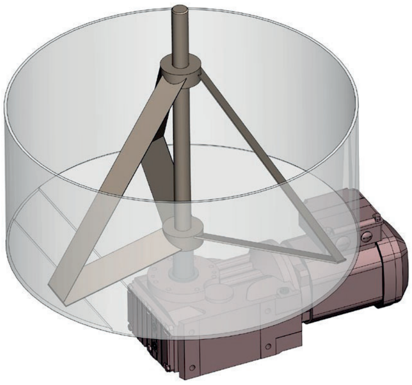
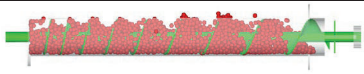
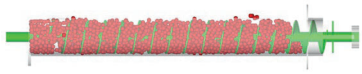
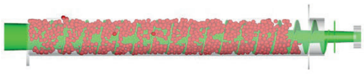
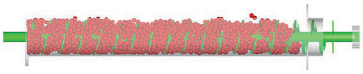


Figure 8. Flow aid device that is most suitable for handling wet cassava grits according to the DEM evaluation.

SCREW

For wet cassava grits, the screw should have a rotation speed ranging from 20 rpm to 80 rpm, thus a correct combination of motor, gearbox and speed controller should be employed. Table 2 shows the uniformity index for each screw type. This index indicates the level of uniformity in which the material is fed to the dryer, where a value of 1 means perfect uniformity. Table 2 also shows the energy consumption per kilogram of material fed to the equipment and the power of the motor needed to rotate the screw.

Table 2. Uniformity of the feeding rate, energy consumption and power requirement for different screw types.

Screw type	DEM simulation	Feeding rate uniformity index	Energy consumption (kJ/kg)	Motor power requirement (kW)
		0.5	0.4	0.02
		0.3	0.7	0.01
		0.3	1.1	0.02
		0.3	1.0	0.01
		0.1	10.0	0.03

As shown in Table 2, the screw-type with the highest uniformity index and lowest energy consumption, thus the most suitable for handling wet cassava grid, was the one with a variable pitch, depictured in Figure 9.

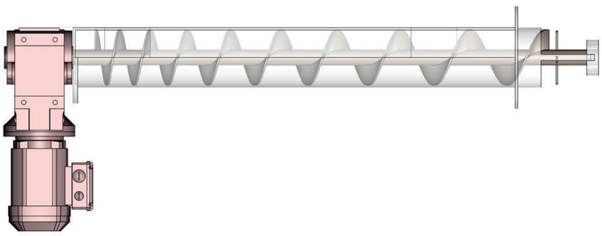
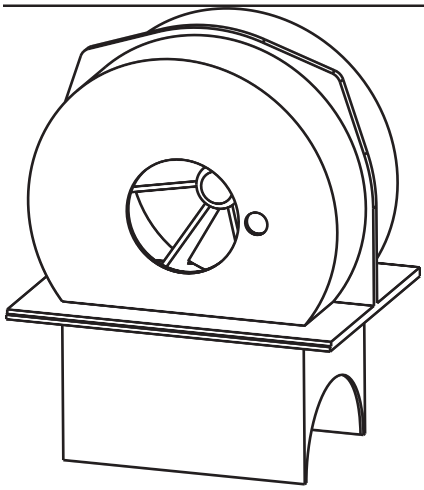
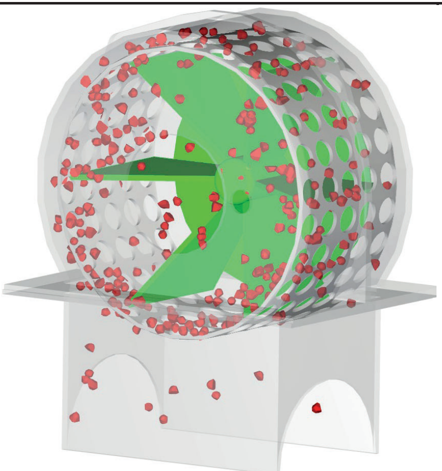
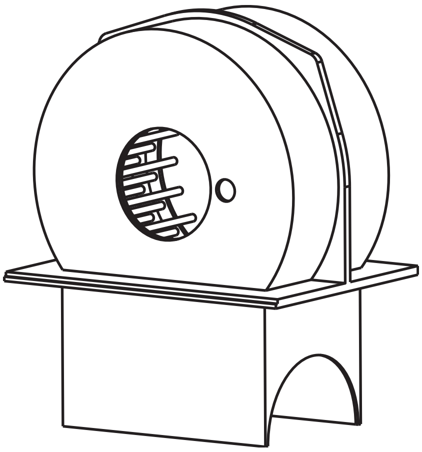
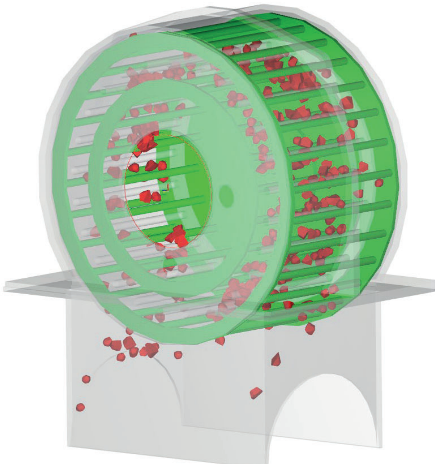
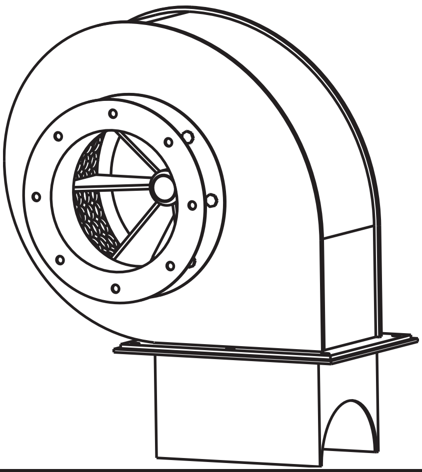
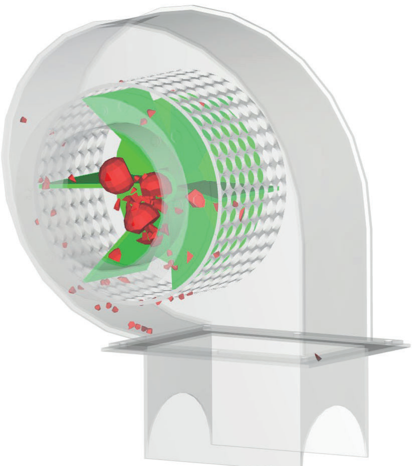


Figure 9. Variable pitch screw was the most suitable for handling wet cassava grits.

DISINTEGRATOR

For wet cassava grits, the disintegrator should be directly connected to the motor's shaft and the minimum rotation speed must be 900 rpm. Table 2 shows the variation in size of the particles obtained from the agglomerate breakage and the power requirement for each disintegrator.

Table 2. Distribution of the particle size and motor power requirement for different types of disintegrator.

Disintegrator type	DEM simulation	Particle size coefficient of variation (%)	Motor power requirement (kW)
		12	3
		14	4
		28	5

As shown in Table 3, the type of disintegrator that broke the agglomerate into more uniform particle size and with the lowest power requirement was the paddle-mill, depicted in Figure 10.

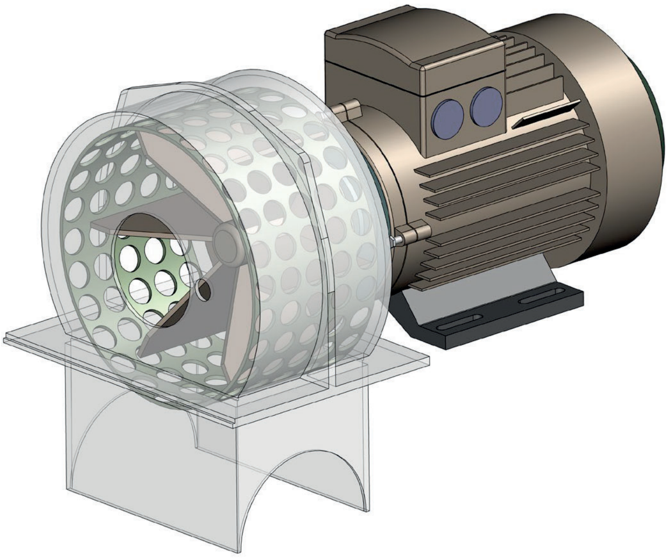


Figure 10. Type of disintegrator most suitable for handling wet cassava grits.

CONCLUSIONS

Based on the properties of the wet cassava grits and the feeding requirements of a pneumatic dryer, a feeding system for cassava pneumatic dryer should have hoppers with vertical walls, equipped with a flow aid device, and a feeder with a screw mechanism, equipped with a disintegrator. Discrete Element Method was used to determine the most suitable shape of the flow aid device, the most suitable type of screw and the most suitable model of disintegrator. Figure 11 shows the feeding system that developed the smallest stagnation zone and provided the most uniform feeding with the lowest power requirement. The 3D CAD assembly is available for visualization and download at https://a360.co/38H9HOV and it will be built by Intermech Engineering (Morogoro, Tanzania). Appendix 1, Appendix 2, and Appendix 3 provide further instruction on how to access it.

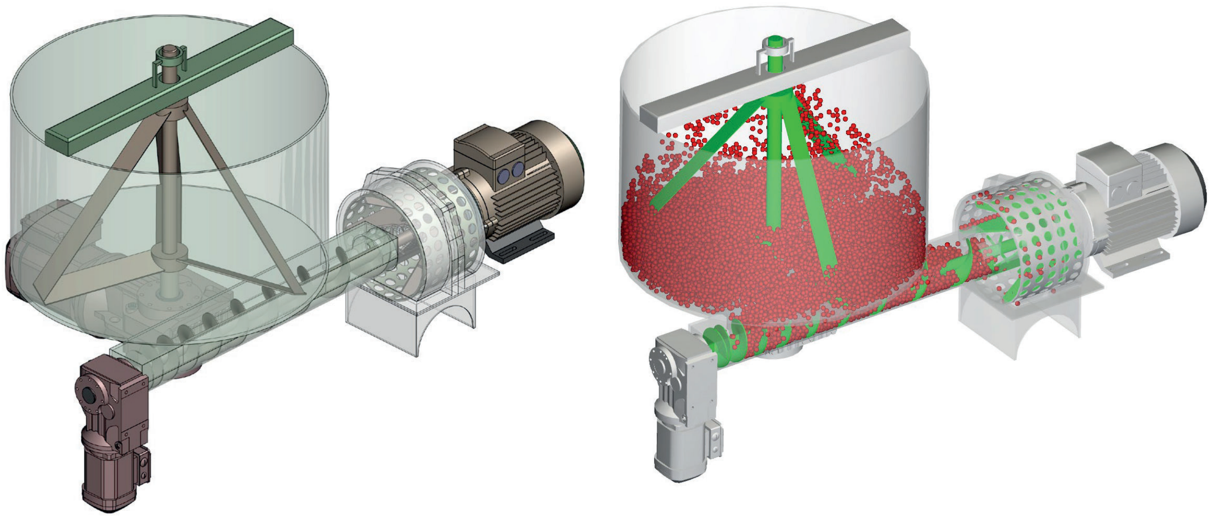
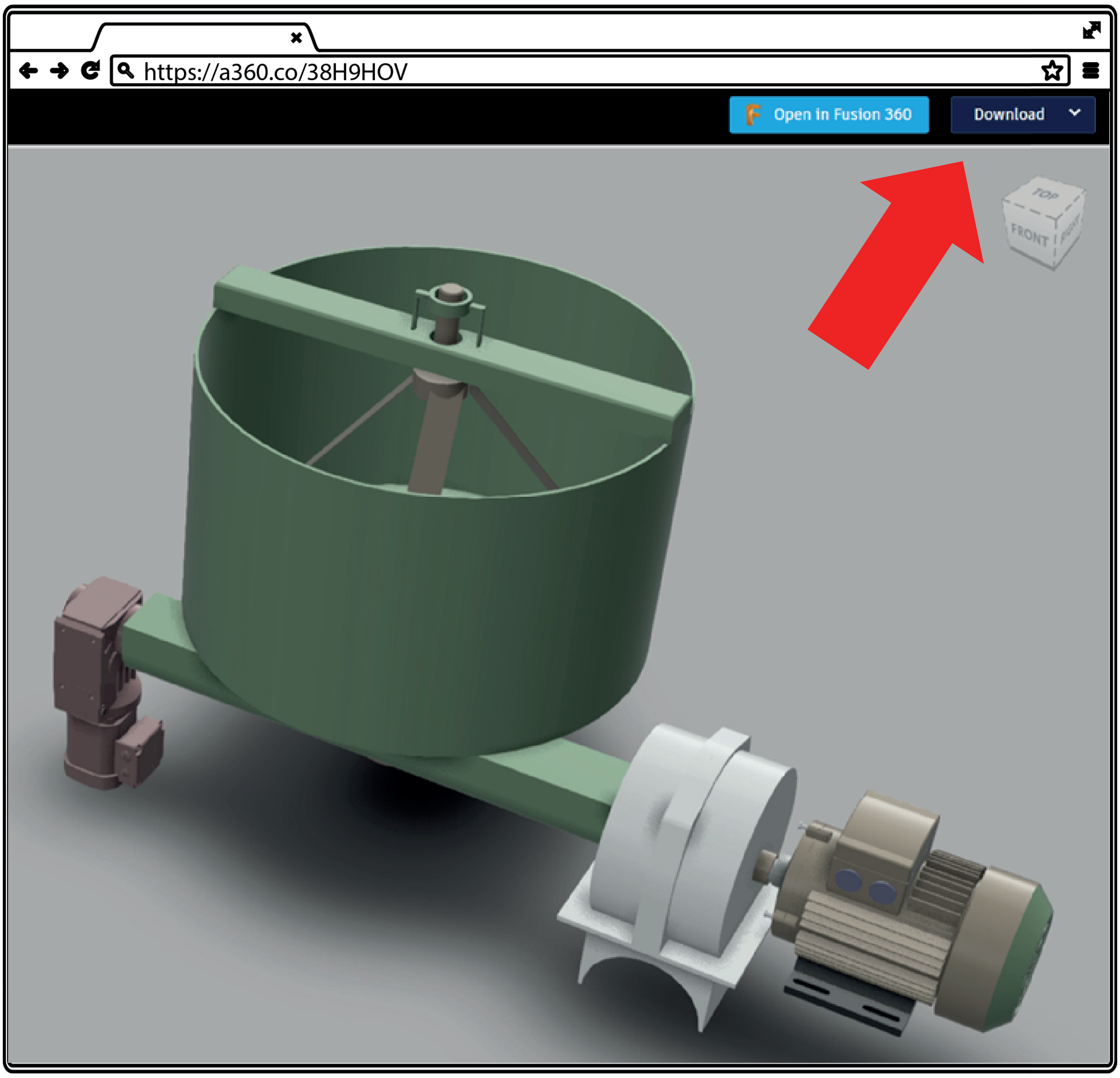


Figure 11. Most suitable feeding system for cassava pneumatic drying.

APPENDIX 1

To visualize or download the 3D CAD assembly, click on https://a360.co/38H9HOV. No registration, password, or login in is required. At this webpage, it is possible to visualize the drawing, make measurements, create cross-sections, and exploded views. To download it, click at the "Download" button on the top right corner of the screen, as shown in the figure below, and choose the desired format (IGES, SAT, STEP, DWG, etc). The file is stored in a 3D CAD cloud service, provided by Autodesk. However, it does not require the use of Autodesk programs (i.e. do not need Fusion 360).

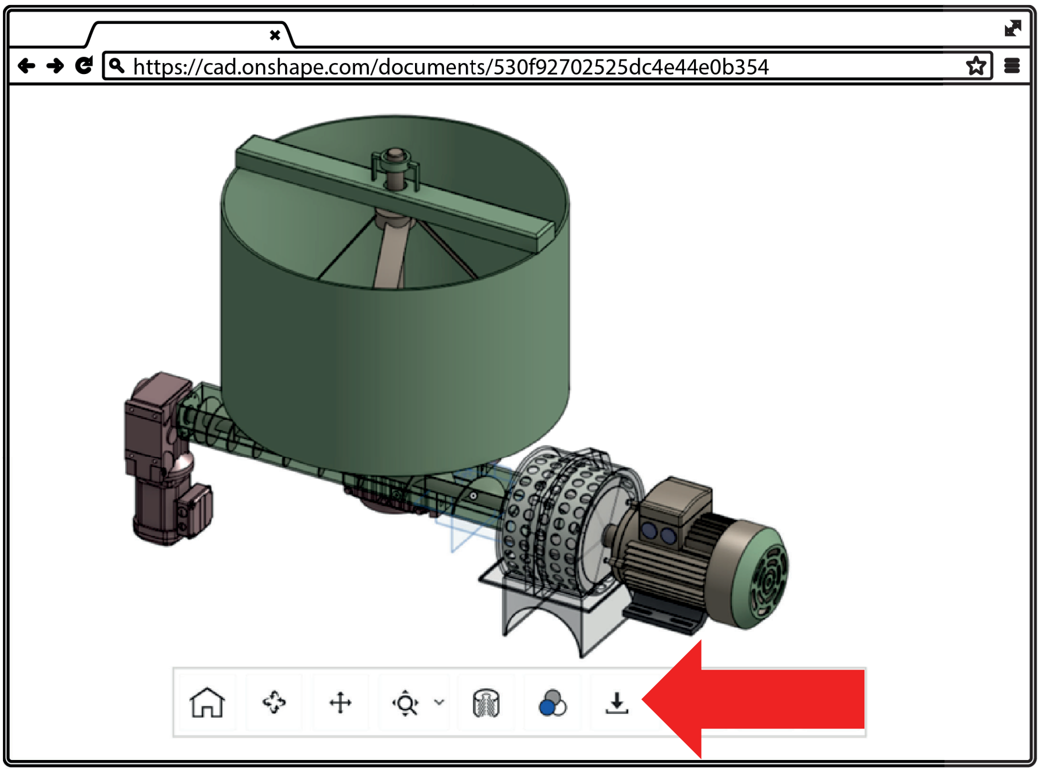


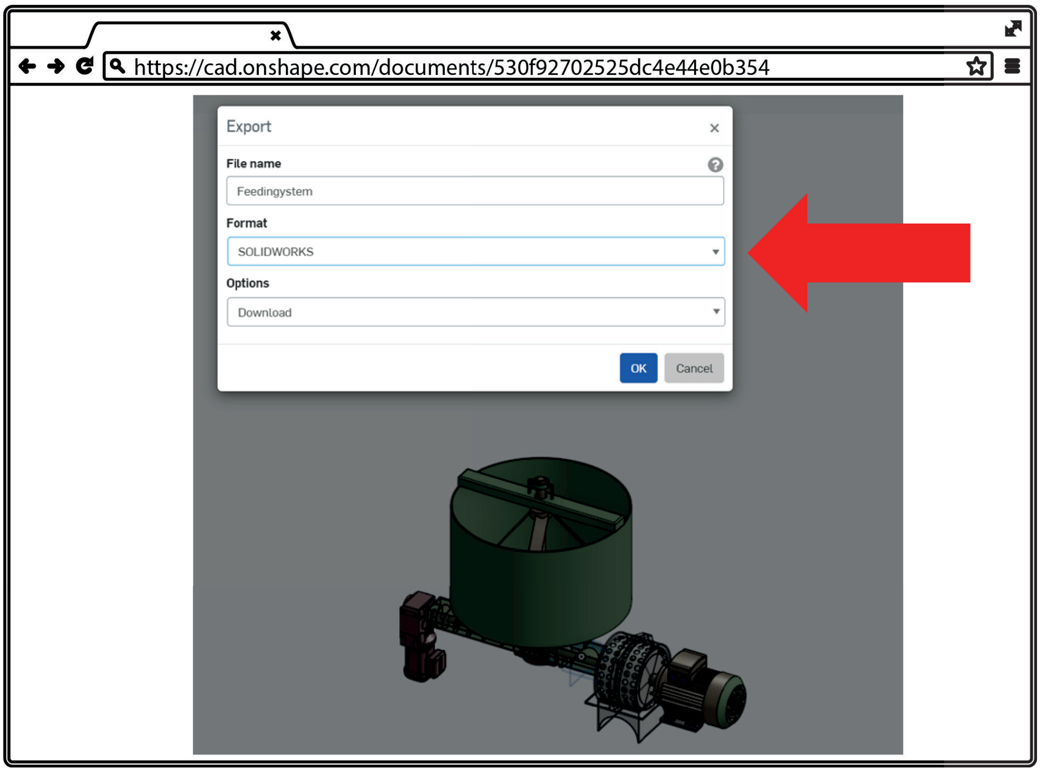
APPENDIX 2

The assembly can also be visualized and downloaded from the Onshape 3D CAD cloud service. Like the service provided by Autodesk, it does not require registration. Simply access it by clicking on:

https://cad.onshape.com/documents/530f92702525dc4e44e0b354/w/893f7f76c468550c4eebc32a/e/b7c98e64b68b61ac960c8bea

This service allows downloading on some formats different than the ones offered by Autodesk, including the option to download for SolidWorks. Click on the "Download" button and choose the desired format, as shown below.

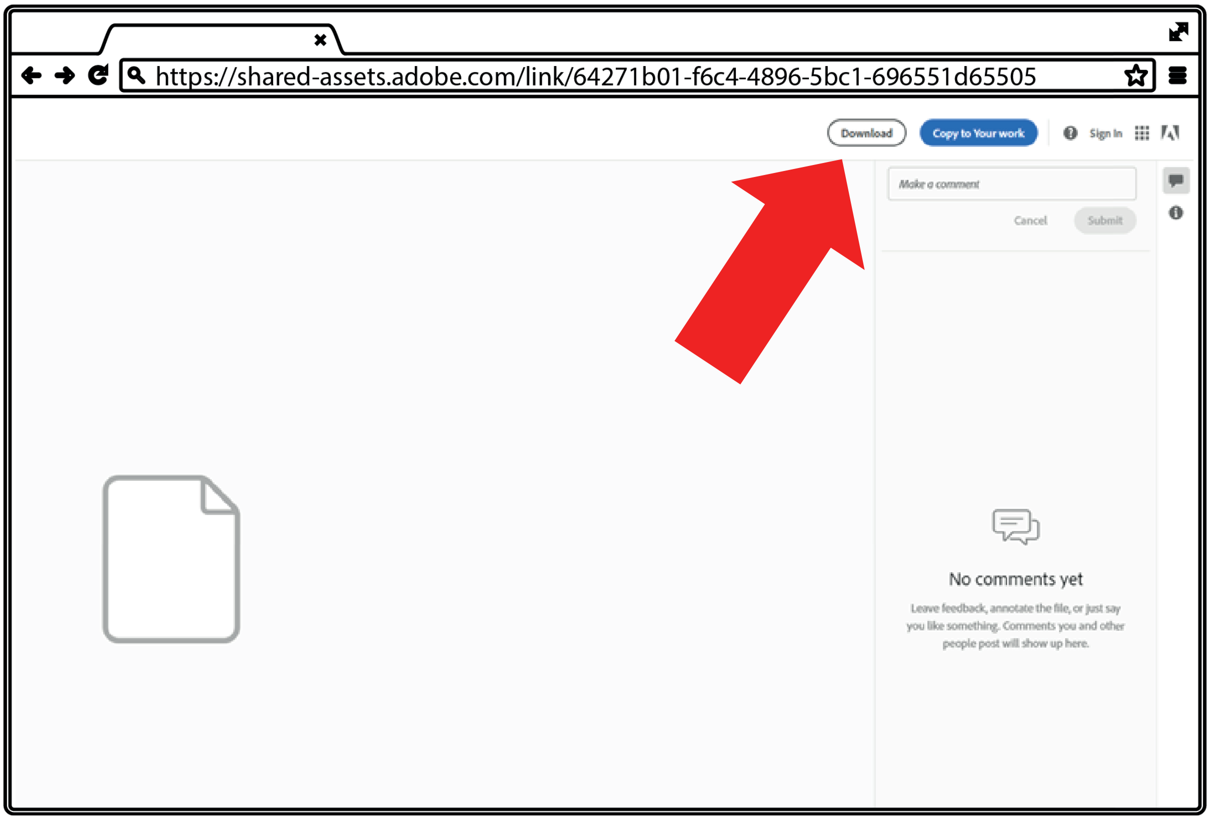




APPENDIX 3

The 3D CAD assembly can also be downloaded from Adobe's cloud service. This service does not provide visualization. It can be download in SolidWorks format only. The download button is on the upper right corner of the page as shown below. Access it by clicking on:

https://shared-assets.adobe.com/link/64271b01-f6c4-4896-5bc1-696551d65505



RESEARCH PROGRAM ON Roots, Tubers and Bananas

CGIAR

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