RTB Working Paper

A novel feeding system for pneumatic drying of cassava

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INTRODUCTION

During cassava processing, the roots are peeled, washed, and grated into a mash. The mash is subsequently mechanically dewatered with a press, and the obtained press-cake is pulverized into wet cassava grits. The wet cassava grits are then introduced to the dryer, and the obtained dried grits are lastly milled into cassava flour.

When cassava is processed using a pneumatic dryer, the wet cassava grits need to be introduced to the drying equipment uniformly, and in a free-flowing form, with no lumps. However, wet cassava grits have poor flow properties and are highly cohesive, with the tendency to agglomerate into lumps. In previous work, the required features of a feeding system for cassava pneumatic drying was investigated. The work considered the flow properties of wet cassava grits and the specificities of how the material should be fed into a pneumatic dryer. It was determined that such a feeding system should have a hopper with vertical walls, equipped with a flow aid device, and a feeder with a screw mechanism, equipped with a disintegrator (Figure 1).

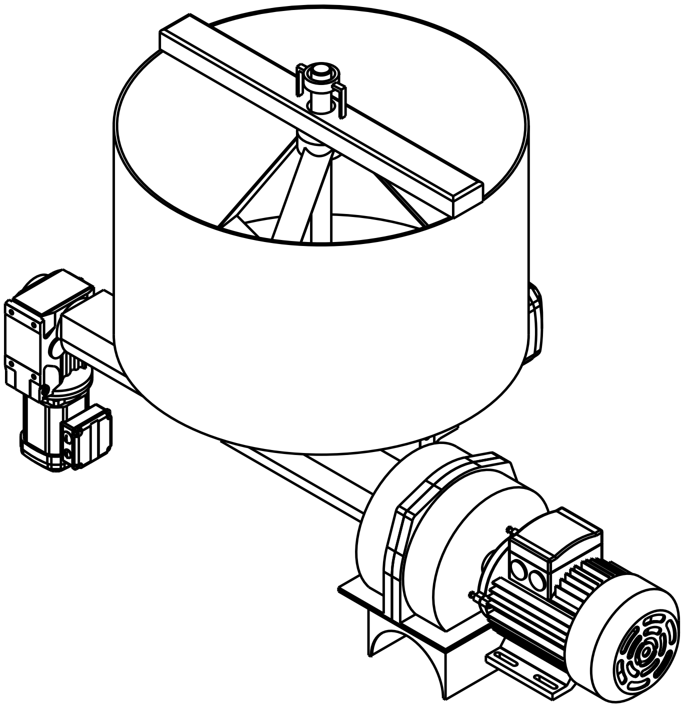


Figure 1. A feeding system for a pneumatic dryer used for cassava processing should have a hopper with vertical walls, equipped with a flow aid device, and a feeder with a screw mechanism, equipped with a disintegrator.

This feeding system, tailored for handling wet cassava grits, is currently being built by Intermech Engineering (Tanzania) and will be installed and tested at the company's pneumatic dryer. It is expected that it will provide the required uniform and steady stream of finely divided solid, well-dispersed to the airstream. However, concern has been raised that because this feeding system has several moving parts, requiring two gearboxes and three motors, and thus, capital cost, maintenance cost and expenditures with electricity might be too high for the small-scale cassava processing enterprise. The objective of this work was, therefore, to develop a novel feeding system, with fewer moving parts and lower costs, but still able to introduce the material in a uniform and a steady stream of small particles, well-dispersed to the airstream, as required by pneumatic dryers.

MATERIALS AND METHODS

The novel feeding system design was based on another innovative feedings system, developed in 2018, and installed in a small-scale pneumatic dryer used for cassava processing in Ghana. This feeding system was composed by a hopper with vertical walls, equipped with a flow aid device. The feeder itself was simply an orifice at the bottom of the hopper (Figure 2a). The disadvantage of this feeding system was the lack of adjustment over the feeding rate, as the material discharge was simply controlled by the size of the orifice at the hopper's bottom. The other disadvantage was that the flow aid device could promote material agglomeration, creating undesired lumps (Figure 2b).

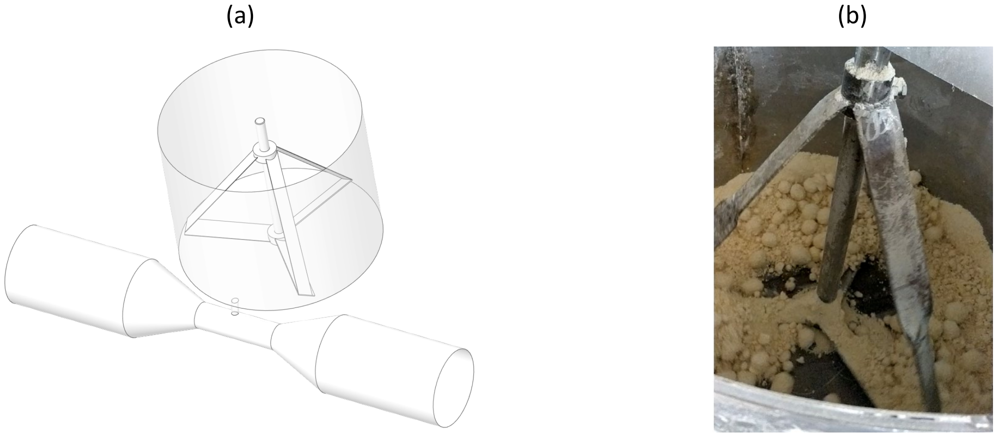


Figure 2. (a) Illustration of the feeding system developed in 2018 for a small-scale pneumatic dryer, and (b) problem of product agglomeration promoted by the flow aid device.

The conceptualized novel feeding system also features a hopper of vertical walls, but with a central orifice outlet. Directly above this orifice, inside the hopper, a cylinder lodges the motor and gearbox that moves the flow aid device. The flow aid device has a curved shape and as rotates, moves the material to the outlet (Figure 3). Different from the feeding system installed in Ghana, this novel system allows adjusting the feeding rate, by changing the rotation speed of the flow aid device.

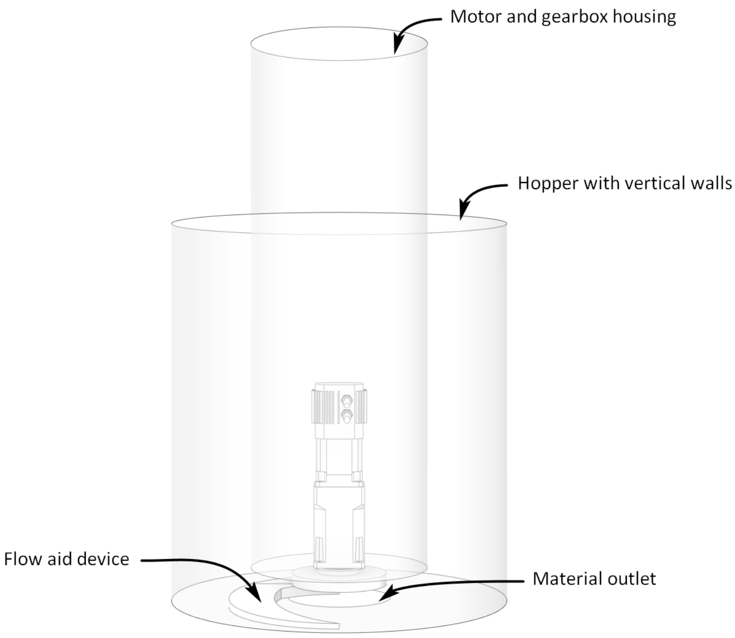


Figure 3. Novel feeding system with central outlet and curved flow aid device that controls feeding rate.

In this feeding system, the flow aid device has a very low profile, generating much lower shear forces compared to the one installed in Ghana, and therefore product agglomeration is not expected to occur. Also, this novel feeding system should be affordable to build and operate, requiring only a single adjustable speed motor with a gearbox. Further, maintenance cost is expected to be low, due to the fewer number of moving parts.

Discrete Element Method (DEM), a numerical model that simulates how particles interact with each other and the surrounding boundaries, was used to develop this conceptualize feeding system into a virtual prototype (Figure 4). DEM was also used to test five different shapes of flow aid devices (Figure 5) and determine their effectiveness on discharging the material, their power requirement, and their likelihood to generate lumps.

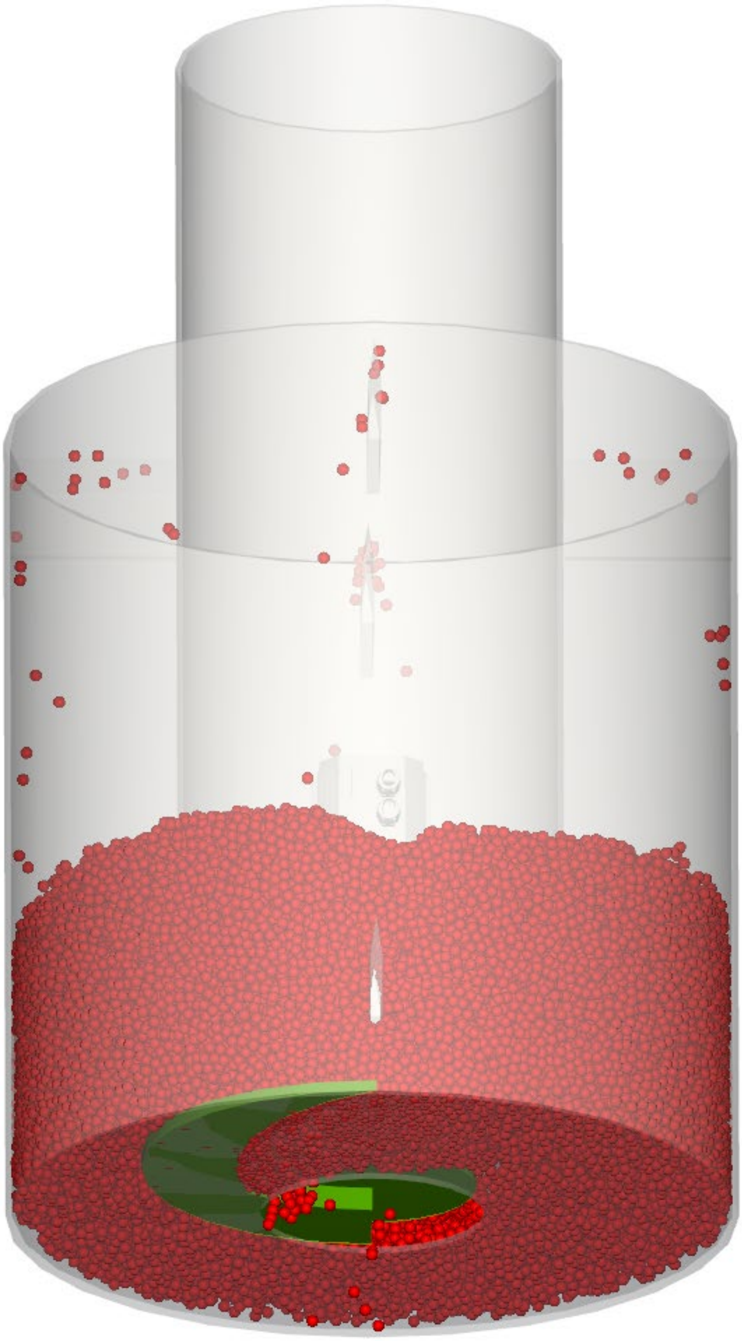


Figure 4. Discrete Element Method was used to develop this novel feeding system.

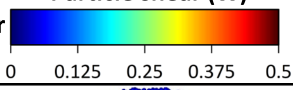
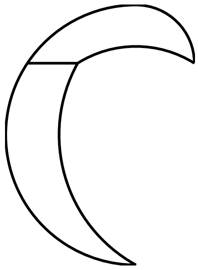
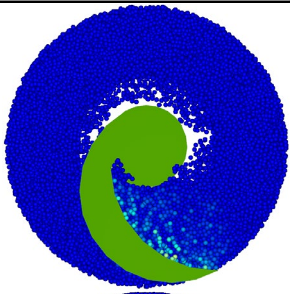
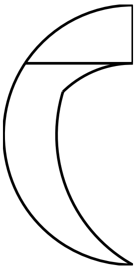
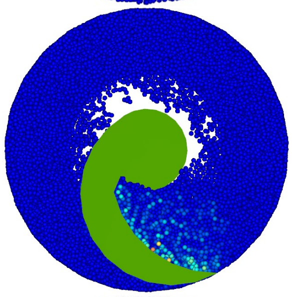
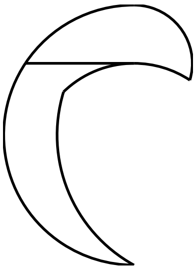
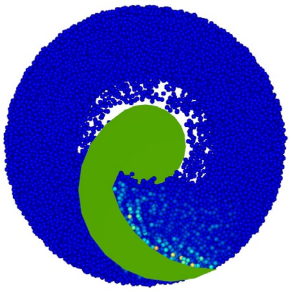
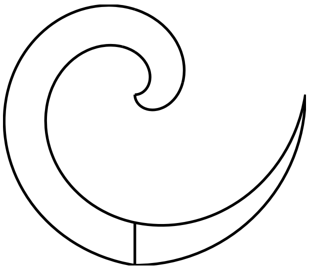
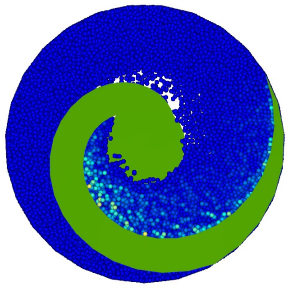
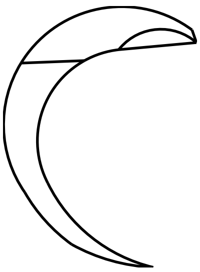
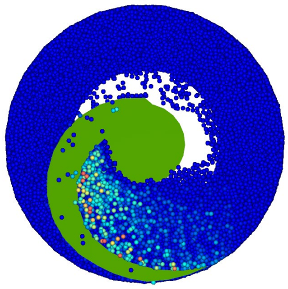
Figure 5. Shapes of the flow aid device evaluated using Discrete Element Method

RESULTS AND DISCUSSION

From the 5 different designs of flow aid device tested using DEM, the one on the first row of Table 1 performed best. It had the lowest energy consumption, represent in kilojoule of energy per kilogram of material fed to the dryer. This design was also among the ones with the lowest motor power requirement.

The feeding rate uniformity-index represents how the quantity of material being introduced to the dryer fluctuated over time, where a value of 1 indicates the highest uniformity. As mentioned before, pneumatic dryers require a very steady and uniform feeding rate. The feeding aid device shown on the first row of Table 1 scored among the ones with the highest uniformity-index, and its uniformity-index was even higher than the screw feeder shown in Figure 1. Finally, maximum particle shear was much lower than 1.6 W, the maximum particle shear of the feeding system shown in Figure 2a, where agglomeration development was observed (Figure 2b).

Table 1. Uniformity of the feeding rate, energy consumption, power requirement, and particle shear, obtained from testing the feeding system with flow aid devices of different shapes.

Shape of flow aid device	Energy consumption (kJ/kg)	Feeding rate uniformity-index	Motor power requirement (kW)	Maximum particle shear (W)	Particle shear (W) 
	2.4	0.6	0.1	0.7	
	3.0	0.6	0.1	0.7	
	3.0	0.6	0.1	0.7	
	3.4	0.7	0.3	0.7	
	10.4	0.6	0.5	0.9	

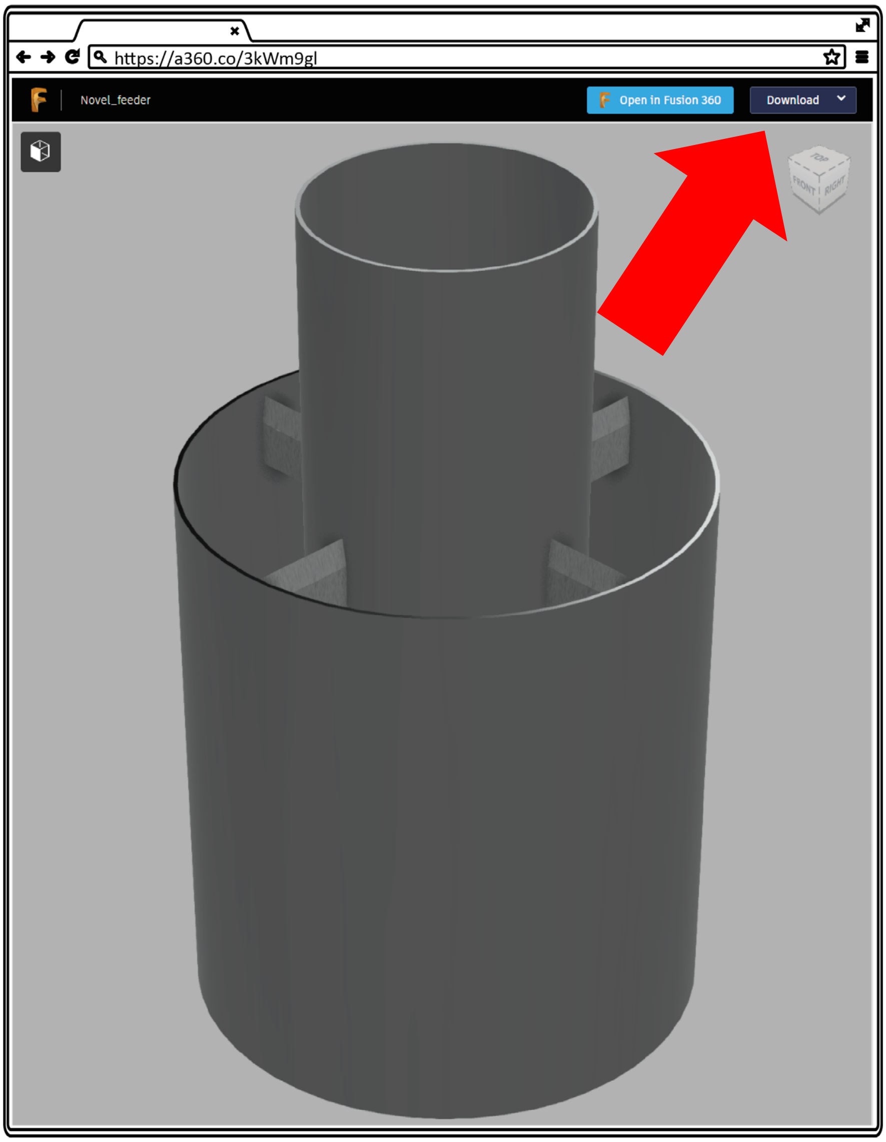
CONCLUSIONS

A novel feeding system for pneumatic drying of cassava was developed and tested using DEM. In addition, the performance of different flow aid devices was evaluated, also using DEM. As a follow-up activity, a prototype will be built by Intermech Engineering and installed on the company's pneumatic dryer. The performance of this novel feeding system will be compared to the performance of the feeding system shown in Figure 1.

APPENDIX: CONSTRUCTION GUIDELINES

The rotation speed of the flow aid device should range from 14 rpm to 40 rpm and therefore the correct combination of motor, gearbox and speed controller must be employed. Also, all parts that come in direct contact with wet cassava grits should be built with a material that does not exchange components with the food, does not react with detergents, and can be easily cleaned, therefore, food-grade stainless-steel is recommended. Parts that do not come in contact with wet cassava grits, like the base structure, if not made of stainless-steel, must be coated with corrosion-resistant paint.

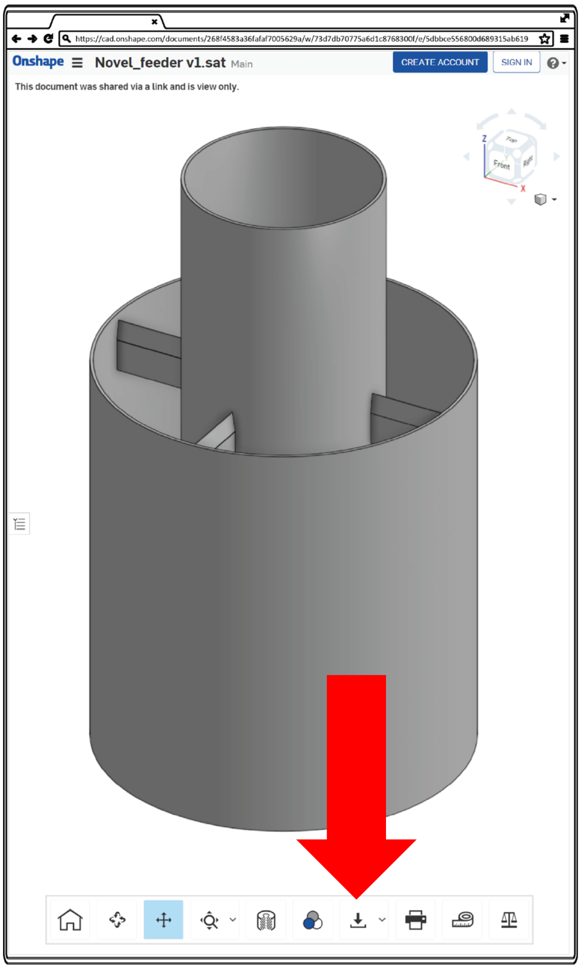
Dimensions should be obtained from the 3D CAD file available at https://a360.co/3kWm9gl. The files are stored in a 3D CAD cloud service provided by Autodesk, is free to use, does not require registration nor the use of Autodesk programs (i.e. do not need Fusion 360). The link allows to visualize the 3D CAD file, make measurements, create cross-sections, and exploded views, all direct from an internet browser such as Google Chrome, as shown below. It works best when opened from a computer, but it can also be accessed from a phone. Further, the file can be downloaded and opened using a 3D CAD software installed locally (i.e. SolidWorks, CATIA, Inventor, etc.).

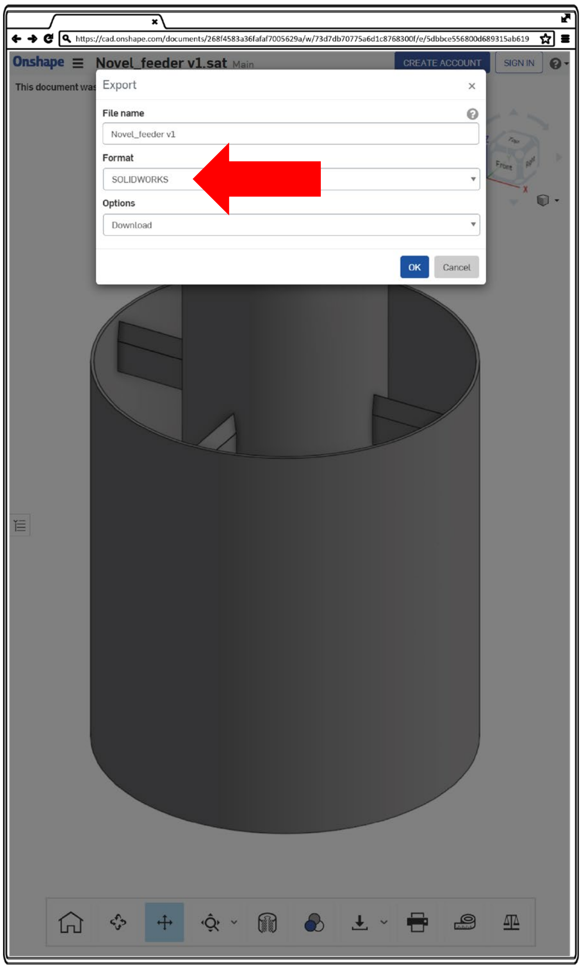


In case of difficulty accessing the files stored at Autodesk 3D CAD cloud service, the assembly can also be visualized and downloaded from the Onshape 3D CAD cloud service. Like the service provided by Autodesk, it does not require registration. Simply access it by clicking on:

https://cad.onshape.com/documents/268f4583a36fafaf7005629a/w/73d7db70775a6d1c8768300f/e/5dbbce556800d689315ab619

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.





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/558f7390-1c4f-4a1e-500b-1e031faaf5d6