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# Identified Flow Problems in Adding Value to Cassava Tuber


## Abstract

*The tubers of cassava cannot be stored for too long. The root perishes soon after harvesting and mass processing of the tubers remain the best way to extend the shelf life. Cassava products and the ingredients are required usually in wet or dry granulation form. Arching, caking, and segregation are common encountered flow problems. Cassava processing steps involve peeling, washing, grating, dewatering, pulverising and sieving. Traditional tools were the options available for these processes at village level. The result of using the traditional method is low productivity. Machines are needed to assist in the value addition; some basic engineering parameters are needed for these designs. Wet and dry cassava mash were evaluated, very useful physical properties in flowability of cassava granules were obtained. Those that are critical for mash conveyors and hoppers designs were noted. TSM (2)1452 varieties of cassava was used in the investigation. Flowability of mash was quantified based on the angle of repose, the shear strength and the mash density. The indicator selected was based on a particular state of the mash in process handling. The results indicated that angle of repose of cassava mash is moisture dependent.*


Keywords: Flowability of mash; Angle of repose; Cassava mash; Mash process handling

## Introduction

Africa's food security situations need substantial improvement (Babalaye, 2005). It is against this background that cassava was viewed as Africa's food security crop because cassava meets the needs of African farmers who work under harsh environmental conditions. Cassava is drought tolerant and serves as a food with many advantages over crops like maize, rice and wheat which often fail because of climate change (Kolawole *et al* 2012). In Nigeria, cassava has already taken over from maize (Sanginga, 2013). It is a staple food for people in Africa and Nigeria is the world leading producer of cassava with more than 34million tons per annum. The root perishes soon after harvesting and mass processing of the tubers into useful products by adding value remain the best way of extending the shelf life. Cassava products and the ingredients are required usually in wet or dry granulation (Abass, 2008).

Cassava tuber processing steps into wet or dry granular involves peeling, washing, grating and dewatering (Samuel *et al.,* 2011). Traditional tools were the options available. Identified cassava products of commercial importance are classified into primary and secondary (figure, 1). The primary products are those products obtained from value addition centres. These include *gari, lafun*-flour, *fufu*, pellets and chips. The secondary products are made for industrial applications.

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They are bio-fuel, ethanol, monosodium-glutamate, glucose-syrup and noodles. The listed and various foods such as crackers, flavouring agents and breads are obtainable from the high quality cassava flour (HQCF).

Machines are needed in the handling steps. Some basic engineering parameters needed for the processing machines design became critical. Various types of conveyors, hoppers, bins or silos are commonly used for the transportation and storage of cassava products. Various flow problems are commonly encountered in the handling when flowing out of a storage bin or hopper. Products may form a rat hole (a self-supporting vertical channel extending from the outlet to the top surface). Sometimes, arches are formed at the hopper outlet, leading to intermittent flow or a no flow scenario.

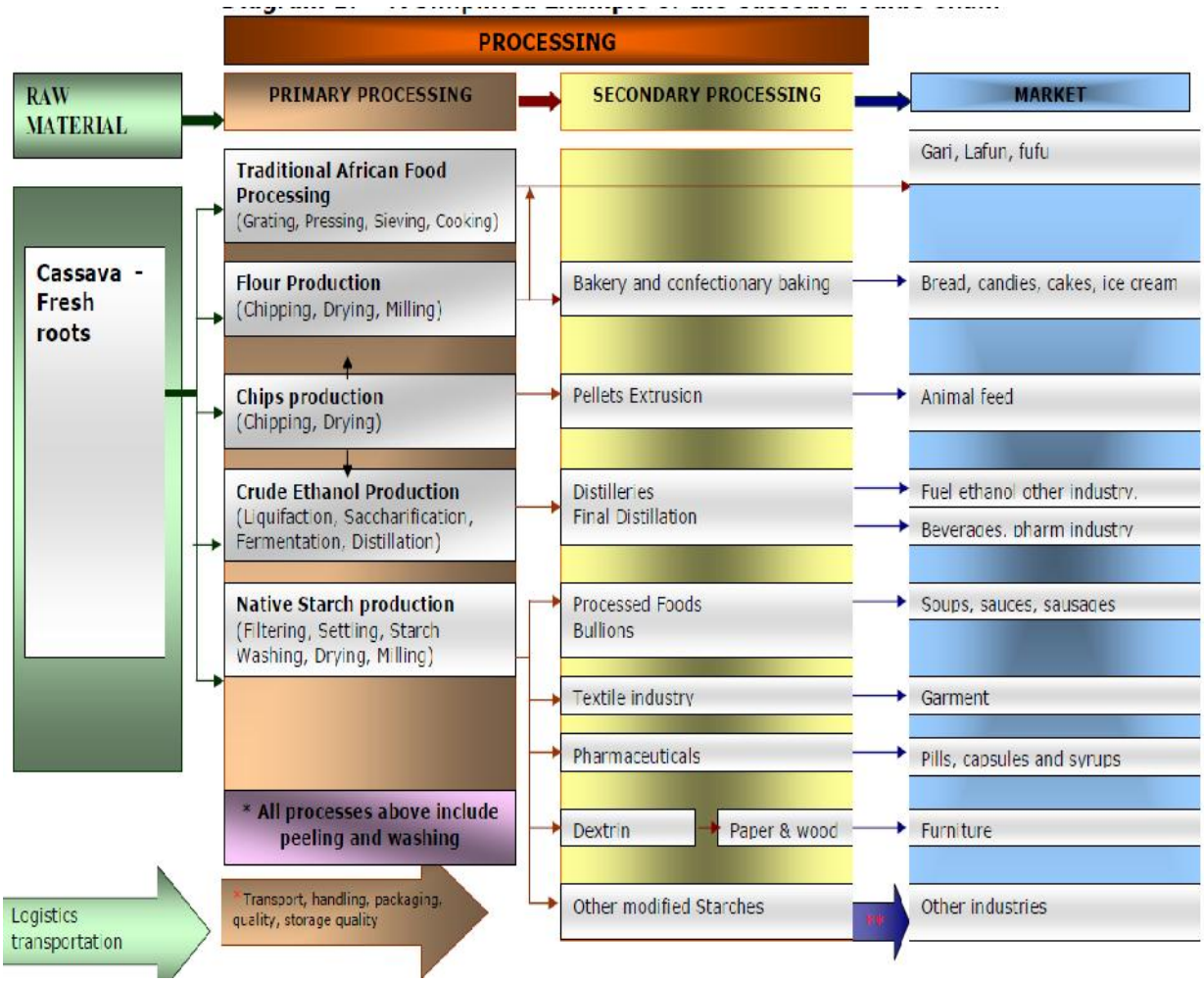


Figure 1: A simplified cassava value chain (Master plan, 2006)

Arching as typical problems at the storage of bulk solids, it occurs when a stable arch is formed above the outlet. The flow of the bulk solid will stop. Ratholing occurs in case of funnel flow if only the bulk solid above the outlet is flowing out and the remaining bulk solid keeps on its place

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and forms the rat hole. Irregular flow occurs if arches and ratholes are formed and collapse alternately. Thereby fine grained bulk solids can become fluidized when falling downwards to the outlet opening, so that they flow out of the silo like a fluid. Flooding can cause a lot of dust, a continuous discharge becomes impossible.
If dead zones are formed (funnel flow), the bulk solid in this zones is discharged only at the complete emptying of the silo, whereas bulk solid, which is filled in later, but located closer to the axis of the silo, is discharged earlier. Because of that, a wide distribution of residence time appears which is disadvantageous in some cases (e.g. in case of storage of food or other products changing their properties with time). If a heap is formed on the bulk solids' surface at filling of the silo, segregation is possible according to particle size or particle density.

Particle interlocking or an increase in cohesive strength can form arches in bulk solids. Particle interlocking occurs when particles lock together mechanically at the outlet. Particles with irregular shapes have a greater chance of forming arches (Schulze,1993). According to Freeman (2000), flowability is a consequence of the combined effects of various physical, chemical and environmental variables. Improper equipment geometry, particle size, shape, surface texture, size distribution, moisture content, compaction condition, storage time, etc. Physical properties are found to have more impact on flowability as compared to chemical properties. Some studies indicated that materials containing spherical particles show good flowability as compared to those with elongated or irregular particles. Elongated or irregular particles might tend to mechanically interlock or entangle with each other, thus obstructing flow and reducing flowability (Schulze, 1993). Thus, flowability issues are generally attributed to the cohesive nature or to the mechanical interlocking with irregular shapes. Much proven scientific understanding of bulk material flow has not been used fully (Bodhmage, 2006). Problems such as arching, rathole formation, flooding and segregation developing in the equipment can have an engineering solution. ISO Standard 3435 indicates the use of the angle of repose for quantifying the cohesiveness of a granular material (Cain, 2002). The static angle of repose is the angle made by a pile of material with the horizontal, the measurement of angle of repose can be completed in less time.

Tilting box method and the fixed cone method has been used to determine the angle of repose (Bodhmage 2006). Measurement of cohesive forces may be very difficult and is beyond the scope of this work. Cain (2002) observed a decrease in the value of the flowability rating with an increase in mean particle size, indicating an increase in flowability. His flowability rating was based on a correlation equation involving the Hausner ratio, the mean particle size and the angle of repose. No quantitative study on cassava mash particles has been done. A better understanding of the relationship between particle shape, size, size distribution and density to the mash flowability could help to eliminate potential flow problems. The root of cassava perishes soon after harvesting and mass processing of the tubers into granules remain the best way to extend the shelf life. The objective of this work therefore is to determine the angles of repose of cassava mash for proper handling.

**Background information**

Bulk granular materials on a horizontal surface normally form a conical pile. The internal angle between the surface of the pile and the horizontal surface is related to density, surface area and

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coefficient of friction of the material (Clover, 1998). To design an appropriate handling machine, the internal angle and angle of repose of granular material are needed. Materials with a low angle of repose forms flatter piles than material with a high angle of repose. Therefore, the tap density of a material can be used to predict both its flow properties and many other parameters, which are important in the overall handling process (Bates, 2007).

The relative importance of inter-particulate interactions is the compressibility index often referred to as Carr's Index and the Hausner ratio. By measuring both the untapped volume and the tapped volume the following can be determined:

**Pour (or Bulk) Density = Mass of material ÷ untapped volume**

**Tapped density = Mass of material ÷ Tapped volume**

**Hausner ratio = Tapped Density ÷ Pour density**

**Carr's Index = (Tapped density – Bulk density) x (100 ÷ Tapped density)**

It is well known that particle size influences flowability, fine particles (< 100μm) tend to be more cohesive and therefore less free-flowing, whereas larger denser particles tend to be free flowing. A Hausner ratio of <1.25 indicates a powder that is free flowing whereas >1.25 indicates poor flow ability. The smaller the Carr's Index the better the flow properties. For example 5-15 indicates Excellent, 12-16 Good, 18-21 Fair and > 23 Poor flow. Particle with high surface to mass ratio are more cohesive than the coarser particle which are influenced by gravitational force (Kale, 2011).

**If** H= Bulk density/Compresed Density = Hausner ratio.

$$H = \rho_B \div \rho_T \qquad (1)$$

Where $\boldsymbol{\rho_B}$ is the freely settled bulk density, and $\boldsymbol{\rho_T}$ is the tapped density The Hausner ratio is frequently used in pharmaceutics as an indication of the flowability of a powder.

The Hausner ratio is related to the Carr index, another indication of flowability, by the formula

$$H = (C / 100) + 1 \qquad (2)$$

$H$ = Hausner ratio

$C$ = Carr index

On a molecular level, the characteristic surface roughness and real area of contact dictates the cohesion and adhesion properties of particles surface (Cain, 2002).

**Bulk density = Mass of granule ÷Volume of granule (3)**

Porosity derived from the values of true and bulk densities when fitted into the equation (Achor, *et al.,* 2010)

$$e = 1\text{-}Bb/Dt \times 10 \qquad (4)$$

Were Bb, is the bulk density, Dt is the true density and **e** is the porosity.

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The static angle of repose to be measured according to the fixed funnel and free standing cone method and the tangent of the angle of repose calculated using the equation:

$$\tan \theta = 2h/d \quad (5)$$

Where h is the height of the heap of powder and d is the diameter of the base of the heap of powder.(Achor, *et al* 2010) .

**Methodology**

Cassava tuber was obtained from IITA farm and made into mash by grating. The tubers were12 month matured, a TMS 4(2)1425 variety was used. The grater used produced cassava mash particles with a diameter of 0.1mm to 2 mm. Flowability of mash was determined based on the angle of repose. This was determined by using an apparatus consisting of a metal box of 300 mm × 300 mm× 300 mm (figure 1.)

Figure 2: Angle of repose measuring box for freshly grated mash

Figure 3: Mash flowing from the box

To determine angle of repose of freshly grated mash, box (figure 1) with a removable front panel was constructed at the workshop. It has a transparent side. The box was filled with freshly grated mash (figure 3) and the front panel of the box was quickly opened, the mash was allowed to flow to their natural slope. The angle of repose was measured (figure 4) from free surface depths at the end of the box and midway along the sloped surface. This was repeated ten times.

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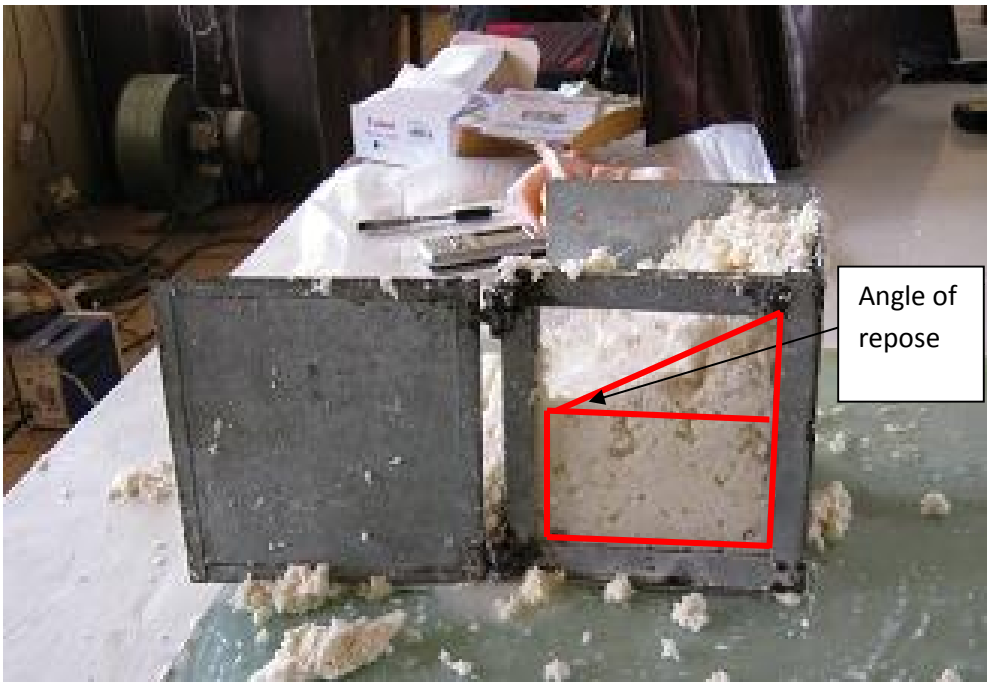


Figure 4: Angle made with the horizontal (Clover, 1998)

To determine angle of repose of pulverized dewatered mash, the sample was treated as powder. The device used consist of a funnel, with an outlet diameter 2 cm, fixed on a metals stand (figure 5). The funnel outlet was kept at a height of 6 cm above the table as per ISO 3435/1. A given quantity of pulverized mash was placed in the funnel and allowed to drop freely through the funnel. A heap of mash made at the base was carefully measured (figure 6) and this was repeated 10 times and done using different moisture content.

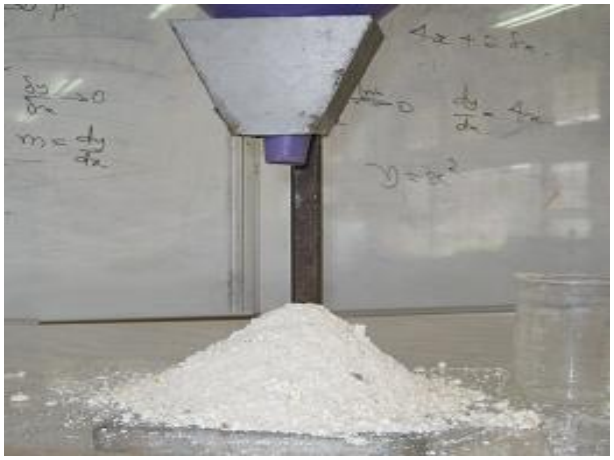

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Figure 5: Measuring angle of repose for pulverized mash.

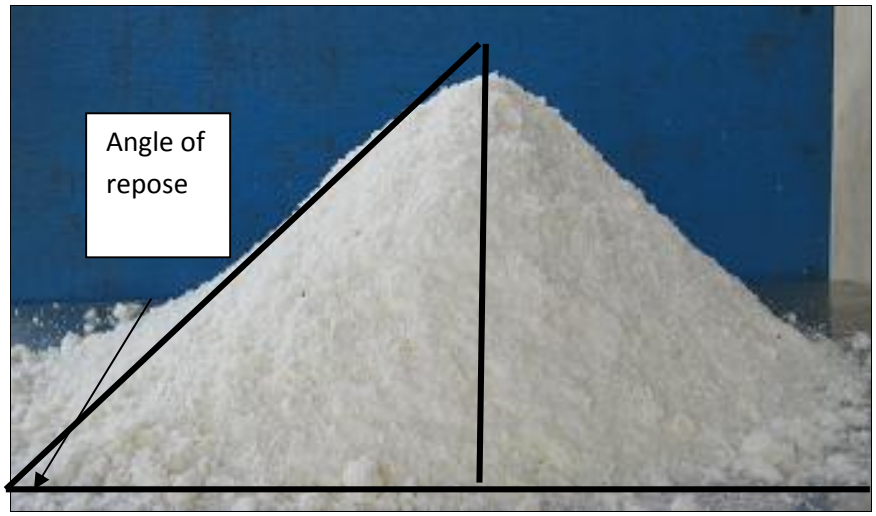


Figure 6: Measurement of the angle of repose of pulverized mash

Angle of repose of cassava mash $\theta = \tan^{-1} 2h \div d$ and this was determined experimentally where h is equal to the height of the particles pile and d equals to the diameter of the mash.
Hausner ratio, Carr index were equally evaluated base on equation 1 and 2 as described Compressibility was used to evaluate the extent of the intentional or unintentional compression that the pulverized mash might suffer during production.

**Result and discussion**

The freshly grated mash was found to be cohesive having a Hausner ratio greater than 1.4 and Carr index of 30 %. The Carr index was found greater than 20 to 25 % therefore classified as non-free-flowing. The Angle of repose of 28° in average was obtained from samples of mash at a moisture content of 72-75% moisture content wet basis. Angle of repose of 32° average was recorded from a mash sample at 62 -65 % moisture content wet basis. Roughly, angle of repose of about 50°and more was recorded with samples as the moisture move to 58% wet basis, it became solid almost 90° as from 50% moisture content wet basis and below.
The particles will require breaking to improve the flowing. This suggested that mash need agitator or cake breaker to move the mash within the machine. Dewatered cake must be turned to particles for easy movement. This was verified by the test carried out on pulverized mash. Angle of repose of 49° at 46% moisture content wet basis was recorded. This form the bases for discharge chute design. Lower angles of repose indicated a free flowing and higher angles indicated a cohesive or poor flowing material.

**Conclusion**

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The results indicated that angle of repose of cassava mash is moisture dependent. Too wet a mash cannot be stored in a silo as arches will form. Stainless steel or containers made of plastics may be better than mild steel as it can change the colour of the product. Cassava mash particles at the level of processing must be handle wet. Smooth surfaces will prevent cohesion and a liitle push of the material may be required.

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