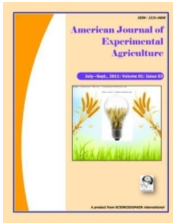

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Some Flow Properties of Cassava Mash in Handling

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Harvested cassava root cannot be stored for too long, it perishes soon after harvesting, and mass processing into storable products is the best way to extend the shelf life of the root. Arching, caking and segregation are commonly encountered flow problems in the processing. Cassava root processing steps involve peeling, washing, grating, dewatering, pulverizing and sieving. Mash conveying and temporary storage in hoppers were considered for improvement, and these require some basic engineering parameters. The flowability of cassava mash was quantified based on the angle of repose and the mash density at given moisture content of mash. The results indicated that freshly grated mash from TMS 4(2)1425 variety of cassava had angle of repose of 28° at a moisture content of 73% wet basis while the pulverised mash with moisture content 45% wet basis had an angle of repose of 49º. The angle of repose of cassava mash is moisture dependent.

Keywords: Flowability; angle of repose; cassava mash; hausner ratio; carr index.

1. INTRODUCTION

Africa's food security needs substantial improvement [1]. Cassava is a drought tolerant food crop with many advantages over other crops like maize, rice and wheat [2]. Cassava has

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already taken over from maize in sub-Saharan Africa [3]. The root of cassava perishes soon after harvesting and mass processing into useful products remains the best way of extending the shelf life. Cassava products are required usually in granulation form [4].The processing steps involves peeling, washing, grating and dewatering [5]. Various foods such as pastries, flavouring agents and breads are obtainable from cassava flour [6], which require machines in the processing. To substantially improve machines for the root processing, re-designing various types of conveyors, hoppers, bins or silos currently in use for transportation and storage of cassava flour need some basic engineering parameters, they are needed because various flow problems are expected in the handling as products may form a self-supporting vertical channel. Sometimes, arches may be formed at the hopper outlet. Particle interlocking may occur with particles locked together mechanically [7]. Physical properties do affect flowability of granules [8]. Flowability issues can be attributed to the cohesive nature or to the mechanical interlocking based on irregular shapes of granules [9]. ISO standard 3435 indicates the use of the angle of repose for quantifying the cohesiveness of a granular material [10]. The static angle of repose is the angle made by a pile of material with the horizontal.

Tilting box method and the fixed cone method has been used to determine the angle of repose [9]. In literature the value of the flowability rating for wheat flours was documented [10]. Flowability rating was based on equation relating Hausner ratio and the angle of repose. It is necessary to document quantitative study on cassava mash particles [11]. A better understanding of the relationship between bulk density of mash and flowability could help to understand and eliminate potential flow problems. 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 coefficient of friction [12]. To design an appropriate handling machine, the angle of repose of granular material are needed. Low angles of repose are for materials with flatter piles. The tapped density of a material can also predict its flow properties and many other important parameters in overall handling process [13]. The objective of this work therefore is to determine the Bulk density and the angles of repose of cassava mash at a given moisture content suitable for proper handling.

Bulk Density = Mass of material ÷ untapped volume (1)

Tapped density = Mass of material ÷ Tapped volume (2)

Carr's Index = (Tapped density – Bulk density) x (100 ÷ Tapped density) (3)

A Hausner ratio of <1.25 indicates a material that is free flowing whereas >1.25 indicates poor flowability [14]. The smaller the Carr's Index the better the flow properties. 5-15 indicates Excellent, 12-16 as Good, 18-21 as Fair and > 23 Poor flow [14]. Particle with high surface to mass ratio are more cohesive than the coarser particle which are influenced by gravitational force [15]. The Hausner ratio is an indication of the flowability of granules.
Hausner ratio [14] = H

$$H = \frac{\rho_T}{\rho_B} \tag{4}$$

Where ρ_B is the freely settled bulk density, and ρ_T is the tapped density. The Hausner ratio as related to the Carr index, provide another indication of flowability, by the formula

$$H=100/ (100-C) \quad (5)$$

Where H = Hausner ratio and C = Carr index

The characteristic surface roughness and real area of contact dictates the cohesion and adhesion properties of particles surface [10]

Like equation 1 above Granules Bulk density = Mass of granule ÷ Volume of granule (6)

The static angle of repose according to the fixed funnel and free standing cone method will serve granules well and the tangent of the angle of repose can then be obtained from the equation 7

$$Tan\theta = \frac{2h}{d} \quad (7)$$

Where *h* is the height of the heap of powder and *d* is the diameter of the base of the heap of powder [16].

2. MATERIALS AND METHODS

A TMS 4(2)1425 variety of Cassava was selected [17,11] and uprooted at 12 month old. The root was grated into mash with particle size between 0.1mm and 2 mm in diameter. The grated mash was divided into two separate samples and labelled W and D. Moisture content of samples was obtained with oven drying method, the sample was heated in an oven at 110ºC for hours until no variation in weight was noticed, and the loss of weight was used to calculate the moisture content of the sample. Sample W was used as wet sample while sample D was dewatered and pulverized to form granules. To determine angle of repose of wet sample [12], tilting box method was used. A fixed box with a removable front panel was constructed. It consists of 300 mm × 300 mm× 300 mm. It has a transparent side. The angle of repose was determined with the box filled with freshly grated mash (Fig. 1) and the front door of the box was quickly opened, the mash was allowed to flow to its natural slope (Fig. 2). The angle of repose was calculated using the measurement taken from free surface depths at the end of the box and midway along the sloped surface. This was repeated ten times at 73%, 60% and 55% levels of mash moisture content wet basis. The angle of repose of dewatered and pulverized mash at 50%, 45% and 40 % moisture content wet basis (M_{wb}.) was determined with the mash cake broken into granules. The ideal moisture content of mash cake was given as the time when cakes can disintegrate into granules without lumps. This was achieved between 47 % and 50 % M_{wb}. An apparatus consisting of a funnel, with an outlet of diameter 2 cm was set up. The funnel was fixed on a metals stand (Fig. 3). 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 and this was repeated 10 times for each sample at given moisture. Angle of repose of cassava mash $\theta = \tan^{-1} 2h/d$ was determined experimentally where h is equal to the height of the particles pile and d equals to the diameter of the mash base. The bulk densities of the samples were determined. Freshly grated mash sample made from TMS 4(2) 1425 at various moisture content was measured using a graduated baker, a weighing (Melter PC 400 model) scale balance.

Fig. 1. Box filled with freshly grated mash

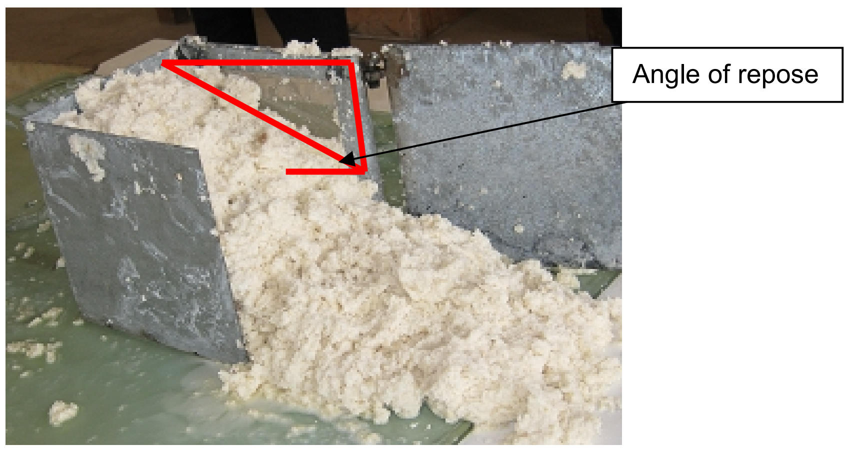

Fig. 2. Mash flowing from the box

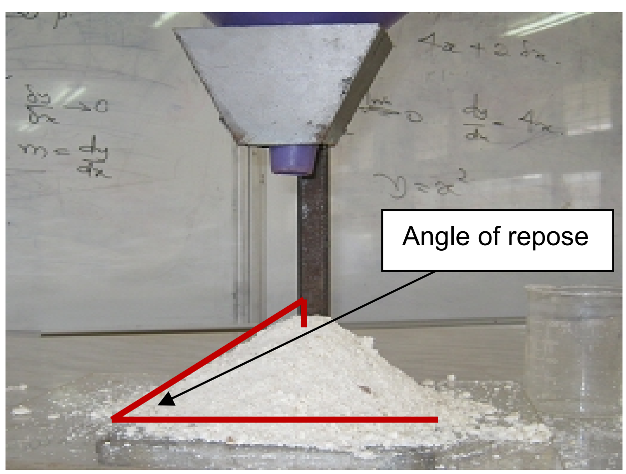

Fig. 3. Measuring the angle of repose for pulverized mash

The volume of beaker used for the samples was $250cm^3$ and mass of grated mash sample recorded. This was used to determine the density and the same procedure was repeated. For the pulverized mash, compressed volume was possible with the granules since it is compressible. Hausner ratio, Carr index were equally evaluated base on equation 1 and 2 as described for the pulverized mash.

3. RESULTS AND DISCUSSION

The flow properties investigated were loose and tapped bulk density of cassava mash made from TMS4 (2)1425, Hausner ratio, and static angle of repose. Freshly grated mash was found to be cohesive as it spreads flatter at moisture content of 73 M_{wb}. The Angle of repose of freshly grated mash was obtained as 28º. The angle of repose of 32º was recorded for mash sample at 65% M_{wb}, and 76º was recorded for sample with sample at 55% $M_{wb.}$ Mash sample became cake at 50% M_{wb} the angle of repose became 87º (Table 1). This was the maximum angle at which the slope of the mash remains stable and the mash particle became firm. When the mash-cake was broken into loose granules, a bulk density of $553kg{\cdot}m^{-3}$ was obtained. After tapping the particles, a bulk density of $1154kg{\cdot}m^{-3}$ was recorded indicating that the mash can be compressed in handling. The Hausner ratio of the mash particles was found to be 2.09, indicating that the mash will not flow easily. The Carr index was found to be 52.1% (Table 2) therefore cassava mash made from TMS 4(2) 1425 can be classified as non-free-flowing material [14]. This suggested that the mash might need an agitator or a cake breaker to move the mash granules within a machine. Angle of repose of 49° obtained at 45% M_{wb} indicated that conveyors required will need a push as the mash proved to be cohesive and poor in flowing. Fine finished surface may be better since mash will not be able to stick firmly to containers or duct.

Table 1. Angle of repose for mash (Wet and pulverized) at different moisture

M_{Wb} of Mash (%) *	Angle of repose	
	Wet-Mash	**Dewatered/Pulverized mash**
73	28º	-
65	32º	-
60	61º	-
55	76º	-
50	87º	50º
45	88º	49º
40	89º	46º

**Moisture content wet basis*

Table 2. Determined flow parameters of TMS 4(2)1425 mash particles

Indicator	Value
apped density	$1154kg{\cdot}m^{-3}$
Bulk density	$553kg{\cdot}m^{-3}$
Hausner ratio	2.09
Carr index	52.1%

4. CONCLUSION

The study showed that angle of repose of cassava mash is moisture dependent. Cassava mash particles at the primary level of processing would be best handled when wet. Smooth surfaces could help prevent stickiness and this may easily allow materials to flow. A little push of the material may be required because; cassava root made into granules may not flow easily, as found from this work. Hausner ratio value in the result shows that cassava mash is a non-freely flowing material. The Carr index was found to be over 25%, which means that agitators may be required whenever conveyors or hoppers are used. This information allows scientists and engineers to predict how cassava mash will behave in their processes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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