Some Flow Properties of Cassava Mash in Handling

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ABSTRACT

Harvested cassava root cannot be stored for too long, it perishes soon after harvesting, mass processing into storable products is the best way to extend the shelf life of the root. Arching, caking and segregation are common encountered flow problems in the processing. Cassava root processing steps involve peeling, washing, grating, dewatering, pulverizing and sieving. Machines are sometimes used in the value addition. Mash conveying and temporary storage in hoppers were considered for improvement, these require some basic engineering parameters. The flowability of cassava mash was quantified based on the angle of repose and the mash density. This was based on a particular state of the mash in process handling. Some physical properties were evaluated at crop process laboratory of the Federal University of Technology Akure. The results indicated that freshly grated mash from TSM (2)1452 variety of cassava had angle of repose of 28° at a moisture content of 73% w.b. While the pulverised mash with moisture content 45% w.b. had an angle of repose of 49°. The results indicated that angle of repose of cassava mash is moisture dependent.

Comment [u1]: State the particular state.

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Keywords: Flowability, Angle of repose, Cassava mash, Process

1. INTRODUCTION

Africa's food security needs substantial improvement [1]. Cassava is drought tolerant food crop with many advantages over other crops like maize, rice and wheat [2]. Cassava has 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 roots processing steps involves peeling, washing, grating and dewatering [5]. Various foods such as crackers, flavouring agents and breads are obtainable from cassava flour [6]. Machines are used in some processing handling steps. To substantially improve machines for the roots processing, re-designing various types of conveyors, hoppers, bins or silos currently in use for transportation and storage of wheat flour need some basic engineering parameters 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 (AN006). 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 (AN006) [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

$$H = \rho_T \div \rho_B \quad (4)$$

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

$$H = (C / 100) \div 1 \quad (5)$$

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

$$\tan \theta = 2h/d \quad (7)$$

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. MATERIAL AND METHODS

A TMS 4(2)1425 variety of Cassava was selected [17][11] and uproot at 12 month old. The root was grated into mash with particles size of between 0.1mm to 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 under specified conditions, and the loss of weight was used to calculate the moisture content of the sample. Wet basis moisture describes the water content of agricultural materials and food products. Sample one was used as wet sample while sample two was dewatered and pulverized to form granules. To determine angle of repose of wet sample [12], tilting box method was used. A fixed box (figure 1) with a removable front panel was constructed at the workshop. 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 (figure 2) and the front door of the box was quickly opened, the mash was allowed to flow to its natural slope. The angle of repose was calculated from the measurement taken (figure 3) 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.c.w.b.) was determined with the mash cake broken into granules. The ideal moisture content of mash cake was given as the time when cakes can disintegration into granules without lumps. This was achieved between 47 % to 50 % m.c.w.b. Sufficient liquid was removed during dewatering. An apparatus consist of a funnel, with an outlet of diameter 2 cm was set up. The funnel was fixed on a metals stand (figure 4). 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. Bulk density of samples were determined.

Freshly grated mash sample made from TMS (2) 1425 at various moisture content was measured using a graduated baker, a weighing (Melter PC 400 model) scale balance.

Figure 1: Angle of repose measuring box for freshly grated mash

Figure 2: Mash flowing from the box

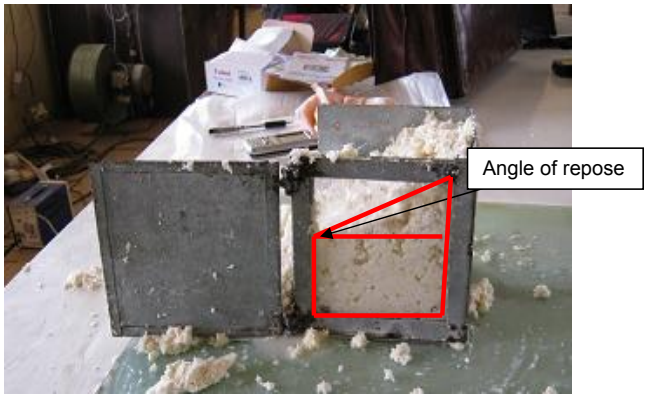

Figure 3: The fresh mash making angle as shown in the viewing glass.

The volume of beaker used for the samples sample is 250cm$^{3.}$ Mass of grated mash sample was recorded. This was used to determine the densities. Same thing was done 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.

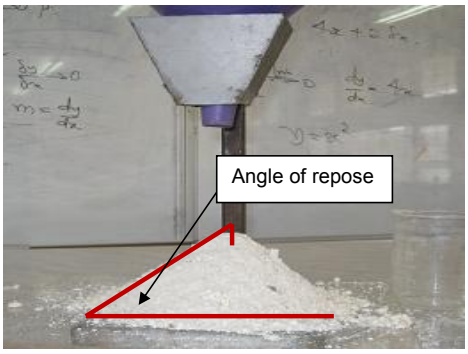

Figure 4: Measuring the angle of repose for pulverized mash.

3. RESULTS AND DISCUSSION

The freshly grated mash was found to be cohesive; it spreads flatter at higher moisture. The Angle of repose of 28° was obtained from sample one at 73% m.c.w.b. Angle of repose of 32° was recorded for mash sample at 65%. Angle of repose of about 50° was recorded with samples at the moisture 55%; it became solid almost 87° at 50% m.c.w.b. (See table 1).

The mash cake was broken into particles with the bulk density of 553 kg/ m^3 after compression the particle 1154kg/m^3 were recorded. The Hausner ratio of the mash particles was given as 2.09, this was greater than 1.4 and Carr index was found to be 47.8%. It was greater than 25 % therefore cassava mash made from TMS (2) 1425 can be classified as non-free-flowing material. This suggested that mash might need agitator or cake breaker to move the mash granules within the machine. Mash cake must be turned to particles for easy movement. This was verified by the test carried out on pulverized mash samples. Angle of repose of 49° at 45% moisture content wet basis was recorded. This could form the basis for discharge chute design. Lower angles of repose indicated a free flowing and higher angles indicated a cohesive or poor flowing material.

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

(%) Mash m.c.*	Wet-Mash	Dewatered/Pulverized mash
73	28°	-
65	32°	-
60	61°	-
55	76°	-
50	87°	50°
45	88°	49°
40	89°	46°

Moisture content wet basis

4. CONCLUSION

The result indicated that angle of repose of cassava mash is moisture dependent as shown on table 1. Too wet a mash cannot be stored in a silo as it can form arches. Stainless steel or containers made of plastics may be better since mash can stick firmly to containers. Cassava mash particles at the primary level of processing would be best handle wet. Smooth surfaces could help prevent stickiness and this may easily allow materials to flow. A little push of the material may be required. Cassava made into granules may not flow easily based on the findings. Hausner ratio value in the result shows that cassava mash is none freely moving materials. The Carr index was found to be over 25%, agitators may be required whenever conveyors or hoppers are used.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

Other authors are very senior professors and scientist. They provided the academic and scientific support I needed to carry out the research.

REFERENCES

1. Babaleye T, Can cassava solve Africa's food crisis? African Business, 2005 No. 314 p.24

2. Kolawole OP, Agbetoye LAS, Ogunlowo AS, Sanni L. and Abass A, Innovative development of Cassava processing Machine as solution to crisis against Agricultural systems. Tropentag 2012 http://www.tropentag.de/2012/abstracts/full/347.pdf Accessed on 7th/2/2014

3. Sanginga N, Cassava to replace Maize farming in Africa, Africa Agriculture News http://www.africa-agri.com/Tanzania-cassava-to-replace-farming-in-africa. 2013

4. Abass A, Recent development in cassava processing, utilization and marketing in East and Southern Africa and lessons learned. Expert consultation meeting at the Natural Resources Institute. University of Greenwich, United Kingdom, 2008.

5. Samuel TM, Igbeka JC, and Kolawole OP, Analysis of working postures among Gari-Frying workers. Indian centre for advanced scientific and technological research Journal of Engineering 2011. 4(2):167-176.

6. UNEDO/FGN, A strategic action plan for the development of the Nigerian cassava industry2006. http://www.nigeriamarkets.org/files/UNIDO%20Cassava%20Masterplan.pdf Accessed on 7th/2/2014

7. Schulze D, (Flow Behaviour of Powders and Bulk Solids Fundamentals 1993), http://www.dietmar-schulze.de/info1e.htm

8. Freeman R., 'The Flowability of Powders - An empirical approach, International Conference Powder and Bulk Solids Handling, June 2000, IMechE HQ, London. http://trove.nla.gov.au/work/35586266?q&versionId=44277003 Accessed on 7th/2/2014

9. Bodhmage A, Correlation between Physical Properties and Flowability Indicators for Fine Powders. A Master of Science Thesis in the Department of Chemical Engineering University of Saskatchewan Saskatoon, Saskatchewan. 2006. http://www.collectionscanada.gc.ca/obj/s4/f2/dsk3/SSU/TC-SSU-07032006115722.pdf Accessed on 7th/2/2014

10. Cain J, An alternative technique for determining ANSI/CEMA Standard 550 Flow ability ratings for granular materials', powder handling procedure 14 (3), 2002, 218-220.

11. Kolawole OP, Agbetoye LAS,and Ogunlowo AS, Cassava mash dewatering parameters, International Journal of Food Engineering: Vol.3:Iss.1, Article4. 2007.

12. Clover TJ, Pocket Reference. Littleton, Colorado: Sequoia Publishing, Inc. 1998.

13. Bates L, Steps to counter segregation in Bulk Solids Handling 2007 http://www.ajax.co.uk/screw.htm Accessed on 7th/5/2010

14. AN006, Particle and powder density, hausner index, and carr ratio rev 0.doc. Accessed on 7th/2/2014 http://www.escubed.co.uk/sites/default/files/density_measurement_(an006)_carrs_index_and_hausner_ratio.pdf

15. Kale VV, Gadekar S, and Ittadwar AM, Particle Size Enlargement: Making and understanding of the behaviour of powder particle system. System Revision 2011. Pharm. 85, http://www.sysrevpharm.org/text.asp?2011/2/2/79/86292 Accessed on 7th/2/2014

16. Achor M, Oyi AR, and Isah AB, Some physical characteristics of Microcrysalline Starch obtained from Maize and Starch. Continental Journals Pharmaceutical Sciences 4: 11 - 17(2010).

17. IITA, Elite Cassava Clones Assessed for Gari Quality. IITA Annual Report & Research Hightlights 1987. Ibadan. Pp. 96-97