CASSAVA CULTIVAR PARTICULES MOTION AND BEHAVIOURAL ANALYSIS IN A HOT AIR STREAM OF A VERTICAL PNEUMATIC DUCT.

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ABSTRACT

Flash drying of cassava cultivar is faced with challenges of lump formation and particles growth process in a vertical pneumatic duct lead to milling and particle discretization with screens or cyclones. The moisture content of the cultivar , pre-treatment of the cultivar and particles size before feeding into the duct, collision or impact of the particles in the hot air stream , gelatinization of cassava marsh and the feeding mechanism affect the particle size, formation and drying of the product. This paper x-rayed the processes involved in the particle size and lump formation due to collisions, air stream flow in laminar or turbulence and the drying kinetics in the long vertical pneumatic duct. Suggestions are made to minimize particle lump formation resulted from collision in gelatinization phase. Creation of gelatinization chamber before feeding and subsequent vortex formation and turbulence along the duct will help to cause particle discretization and losing in the flash duct and this intermittent incorporation of the C D channels that helps in building pressure and reducing pressure resprctively.

Key words: cassava cutivatar, particle lamp formation, vortex and turbulence ,C D channel, vertical pneumatic duct.

1.INTRODUCTION

Drying is an essential process used all over the world for many industrial and domestic purposes such as the preservation of farm products. It helps in reducing the water activity of the products to a level below which deterioration doesn't occur for a definite duration [1]. The drying process helps to achieve better product quality, longer safe storage period and reduction in post-harvest losses. The reduction in post-harvest losses ensures more food availability for growing world population [2]. From informations gathered in Edo state at Enwan and other parts of the Akoko-Edo local government Area, Local frying of gari involves repetitive pressing, scrapping and stirring of the sifted mash in a frying pan over a fire. The pressing of the mash against the hot surface of the hot frying pan called 'AGBADA' in most part of Nigeria it is made of aluminium, results in the toasting of the gari particles; starch so pressed out from the starch granules coats the gari particles and is partially gelatinized to form a thin enveloping film. Thus, under the microscope, a gari particle is seen to be composed of a small grain of cassava coated by a thin film of gelatinized cassava starch. When placed in water or otherwise wetted, the grain absorbs moisture through the partially gelatinized starch film and swells. After frying, the hot gari is spread out to cool and has a moisture content of 13% to 16%, wet basis, which is the usual range of moisture content of fresh gari found in the local markets. At this range of moisture content, the gari can keep for about two weeks without deterioration, provided that the gari is initially uniformly cooled and subsequently stored under conditions that do not permit re-absorption of moisture from the ambient environment . [Odigboh, E.U. 1978]. Manual frying of gari is a hot business; the woman sits near the fire for the hour-long batch process, sweating profusely and pressing, scrapping and stirring continuously to obtain an average of 3.5kg of gari .[Ibe. D.G. 1979]. Naturally, the manual frying process is not quite hygienic as there is ample opportunity for contamination from sundry sources including drops of sweat from the body of the operator. Hence ,there is need to mechanized the garification process which will necessitate torough design of a gari frying machine suitable for the small and medium-scale processors who account for over 95% of the gari consumed in most of Nigeria. Wet bulb drying or flash drying has played a vital role in food processing and chemicals industries. The vertical pneumatic duct is characterized with laminar and steady flow. But the formation of shock due to bend (elbow) and voltage fluctuation effect on the blower may initiate a transition phase to turbulence. In the vertical pneumatic duct, the major part is of uniform length. Hence, the flow in the duct as laminar but the momentum possessed by each particles differs as they are of difference sizes. Hence, the impact force differs on collision. Whether elastic and inelastic after impact particle lump formation propagation involves the sticking of the particles which is governed by the level of impact, wetness of the particles and the galeritirization phase. Large particles are dragged along the duct while fine particles flow fast, on impact, they stick on the large particles to form a larger particles . Thus, particles growth continue along the duct during drying ,the strinkages of these particles reveal the formation of flakes at the chute of the cyclone and are characterized with lumps. The mass balance is perfect and at the exit of the suction blower particles are collected with bag.The lumps or flakes resulted from the flash dryer do not guarantee immediate utilization or consumption, this leads to the drudgery in the milling these lumps and screening or descritization into particle size for grading of the productwith the use of cyclone or screens.In most of the sites visited in Umuahia ,Abia state, IITA Ibadan ,Oyo state, flash dryers are seen with uniform channels of about 12m and swollen parts of two at a diameter one third or half greater than the uniform channel and both are 4m in length meant to build pressure and reduce speed of the hot stream this instantaneous delay at these two regions proper drying but this do not eliminate the formation of lumps in the product since they have been formed in the uniform channel.

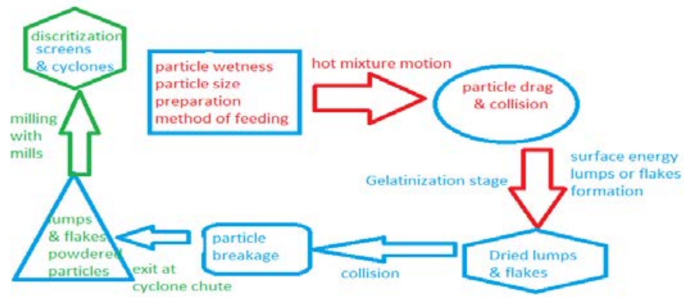

Fig 1.particles of cassava cultivar motion ,collision and lumps formation analysis.

2.MODELLING

The motion of the particles in the hot air stream is assume to be equal in velocity of the air stream. Hence, the difference in the momentum possed is due to the difference in their masses. As the particles of masses $(m_1, m_2, m_3, ---, m_n)$ move concurrently with the speed (v) of the hot stream.Considering that the masses of the particles in the hot stream in the pneumatic duct.

$$m_1 > m_2 > m_3 > ---m_n$$

It implies that the paticles possessed different momentum

$$m_1u > m_2u > m_3u > ---, m_nu$$

In the hot stream with the laminar flow in the vertical duct , particles under goes both elastic and inelastic collision. The collision initiates both particles Integration ─ Lump formation and disintegration. These two processes are governing the wetness of the particles, moisture content of mash or the cassava cultivar on entering the flash duct and gelatinization. Smaller particles on colliding with larger particles may stick together or fragment to form other smaller ones. The cassava cultivar contains more of starch, hence, at a temperature between (30─75)° C the cultivar would gelatinize to become too sticky. The period of gelatinization, the cassava cultivar is susceptible to form lumps as it is sticky.In the domestic frying of cassava mash, gelatinization period involves high or vigorous stirring to pulverize the particles to have finely loose Mani hot powder (garri) after frying. Some cultures like the people of Edo North in Edo State – Enwan, opameri people, Owan people, agenebode, jattu use red oil to weaken the starch content of cassava mash during frying to avoid gelatinization. Such garri product do not have lump after the domestic frying but the white garri are stirred vigorously to avoid lumps formation within the period of gelatinization.

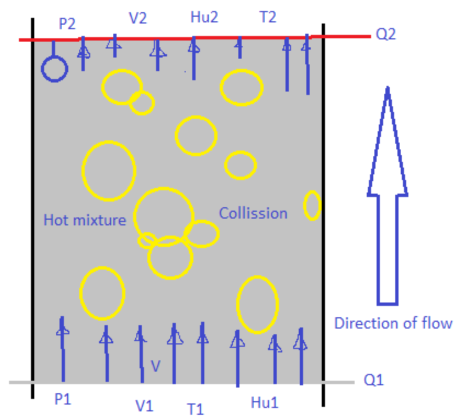

Fig 2. Control volume exhibiting particle behavior

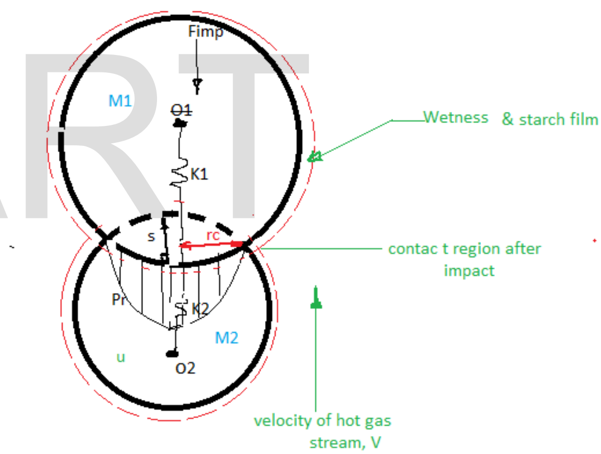

Fig 3.Contact geometry by perfectly plastic deformation of the spherical Particle and pressure build up in particle

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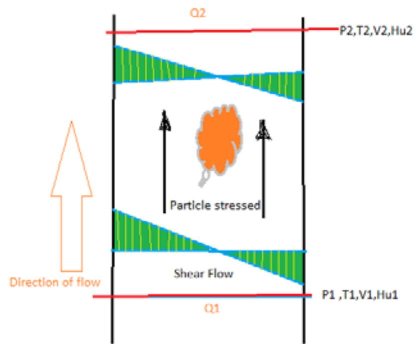

Fig 4.shear flow may initiate flakes formation

In the pneumatic duct, there is no means to stir vigorously and no oiling. Hence, gelatinization control becomes a problem in flash drying of cassava cultivar. After flash drying the products is characterized with lumps and flakes, hence, the need to mill this product to produce cassava flour. However, after milling particles discretization will be done by passing the milled products through screen(sieves) or cyclones for grading and standardization. This paper work tries to analyze the processes involves in lumps formations, visualize the collision of this particles to form lumps or flakes and suggest possible solution to avoid these formations.

3.MODELS

Assumptions

The followings assumptions were made in order to conceptualize the cassava cultivar particles in hot air stream in the vertical pneumatic duct.

1. Cassava cultivar particles are spherical.
2. Collision is either elastic or inelastic
3. Lumps formation is within the gelatinization stage
4. The hot air stream flows is laminar uniform and stead in the vertical pneumatic duct

4.IMPACT LOADING

Impart loading is complex in analysis of collision that involves displacement, material non-linearity, elastic and plastic instability, post buckling strength, coulomb friction and material behavior under high strain rate. But with a few assumptions and principles problems involving impact loading can be resolved. Responses after impact of collision is deformation which could be analyze by energy and momentum conservation. The kinetic energy of the impacting bodies is partially converted to strain energy as part of it is also dissipated through friction and local plastic deformation.

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$$K_E = {}^{1}\!/_{2}\, MV^2 = {}^{1}\!/_{2}\, \frac{W}{g} V^2 \quad (1)$$

$$W = Mg \quad (2)$$

Strain energy of deformation as depicted in fig.

$$E_P = \int_0^y Fdy = \int_0^{y_{max}} Kydy \quad (3)$$

$$E_p = {}^{1}\!/_{2}\, Ky_{max}{}^2 \quad (4)$$

maximum deformation becomes

$$y_{max} = V\sqrt{\frac{W}{Kg}} \quad (5)$$

$$y_{max} = \sqrt{\frac{2K_E}{K}} \quad (6)$$

The maximum deformation force

$$F_{max} = Ky_{max} \quad (7)$$

In elastic collision no energy is lost because non goes into yielding or friction resistance.

From Newton's law

$$F = Ma = M\frac{dv}{dt} \quad (8)$$

$$Ma = Fdt \quad (9)$$

$$\int_{\Delta t} Fdt = M\int_{\Delta v} dv = M\Delta v \quad (10)$$

$$F_{imp} = \frac{m\Delta v}{\Delta t} \quad (11)$$

For the collision to be inelastic the impacting body or target possible been crushed or squashed. This is likened to an insect striking to an automobile wind shield.

5.RELATIVE MOTION AND INTERNAL HEAT GENERATION IN THE FLASH DUCT

Consider the figure depicting cassava cultivar particle in relative motion with the hot air stream

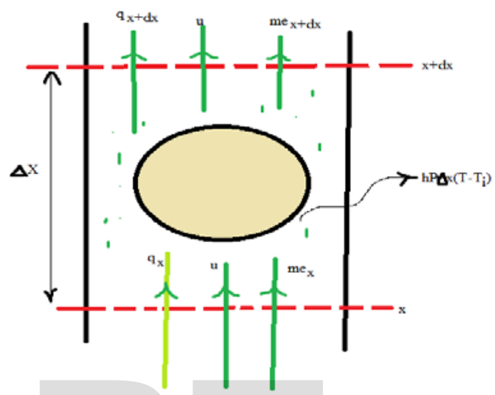

Fig 5. paticle relative motion with hot air

The relative motion between the cassava particles and the hot gas stream and internal heat generation in the flash duct. an energy balance for such a system should be done and analysed, we consider a small differential control volume of length, dx. the heat lost to the environment by radiation is assumed to be negligibly small. The energy is conducted, convected and transported with the material in motion.

$$q_x + me_x + GA\Delta x = q_{x+dx} + me_{x+dx} + hP\Delta x(T - T_i) \quad (12)$$

Where

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m =the mass flow,

ρAu which is assumed to be constant;

ρ, the density of the material;

A=the cross-sectional area;

P= the perimeter of the control volume;

G=the heat generation per unit volume and

u= the velocity at which the material is moving.

Where

$$de_x = C_P dT \quad (13)$$

Using a Taylor series expansion,

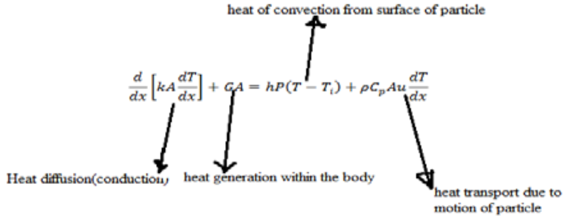
$$m(e_x - e_{x+dx}) = -m\frac{de_x}{dx}\Delta x = -mC_p\frac{dT}{dx}\Delta x \quad (14)$$

Fourier's law

$$q_x - q_{x+dx} = \frac{d}{dx}\left[kA\frac{dT}{dx}\right] \quad (15)$$

Combining the equations we have

$$\frac{d}{dx}\left[kA\frac{dT}{dx}\right] + GA = hP(T - T_i) + \rho C_p Au\frac{dT}{dx} \quad (16)$$



Derived from the heat diffusion (conduction) within the cassava cultivar, from heat generation within the body to convection from the cassava cultivar particle surface to ambient after leaving the chute of cyclone, and the heat transport due to the motion of the material . The temperature

in the medium as a function of space at steady state and as a function of time during the transient state

6.CASSAVA CULTIVAR PARTICLE AS A POROUS

The flow of fluid in a saturated porous media was quantified by a simple, phenomenological,

linear relation by *Darcy* in the nineteenth century (Darcy 1856). Darcy's law relates

the pressure drop (head) to the flow rate across a porous column. The following relation

can be written from such observations

$$u_i = -\frac{k}{\mu}\frac{dp}{dx_i} \quad , i = 1,2 \; \& \; 3 \; dimensional\ flow \quad (17)$$

Where

ui are the seepage velocity components,

κ (m2) is the permeability of the medium,

μ is the dynamic viscosity of the fluid,

p is the pressure and *xi* are the coordinate axes.

Example for two-dimensional flow, velocity components can be given

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$$u_1 = -\frac{k}{\mu}\frac{dp}{dx_1} \quad (18)$$

$$u_2 = -\frac{k}{\mu}\frac{dp}{dx_2} \quad (19)$$

A relationship for the drag force was introduced by Forchheimer, in fig .7

$$D_p = au_i + b{u_i}^2 \quad (20)$$

which is balanced by the pressure force as follows

$$au_i + b{u_i}^2 = -\frac{dp}{dx_i} \quad (21)$$

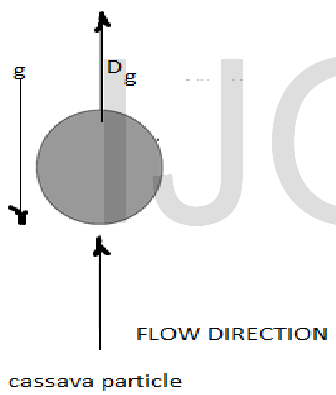

Fig 7.Drag force on a porous medium cassava cultivar particle

In the above equation, the first term on the left-hand side is, in essence, similar to the linear drag term introduced by Darcy, and the second term is the nonlinear drag term. The parameters *a* and *b* are determined by empirical relations and one such correlation was given by Ergun (Ergun 1952), that is,

$$a = 150\frac{(1-\epsilon^2)}{\epsilon^3}\frac{\mu_f}{{d_p}^2} \quad (22)$$

$$b = 1.75\frac{(1-\epsilon)}{\epsilon^3}\frac{\mu_f}{d_p} \quad (23)$$

where, d_p is the solid particle size in a porous medium, different ranges of the bed porosity, ϵ_,

and ρf is the fluid density. The above solid matrix drag relation can also be expressed interms of the medium permeability κ by defining

$$k = \frac{\epsilon^3 {d_p}^2}{150(1-\epsilon)^2} \quad (24)$$

The energy conservation equation

$$[\in (\rho C_p)f + (1-\in)(\rho C_p)s]\frac{dT}{dt} + (\rho C_p)f u_i\frac{dT}{dx_i} = k\left(\frac{d^2T}{{dx_i}^2}\right) \quad (25)$$

where, *t* is the time, *c*p is the specific heat, *T* is the temperature and *k* is the equivalent thermal conductivity. The subscripts f and s stand for the fluid and solid phases respectively

7. UNEQUAL DRYING

Particles with smaller diameters or sizes will dry faster than the larger particles, and below some diameter the particles will be completely dry prior to reaching the end of the drying column. This is not neglected by first calculating the initial (i.e., at injection) amount of water contained in each particle class and then keeping track of the cumulative amount of water evaporated from each class. At the point where the cumulated amount reaches the initial amount, the heat required to elevate the particles temperature from its surface temperature to the gas temperature is subtracted from the gas, and from then on the particle in that class gives up heat as it progresses upward in the drying column in equilibrium with the gas. Heating the particle in a class within a single "slice" is, of course, an approximation that leads to a local distortion in the temperature profile, but the error in the overall drying process is small due to subsequent drop in the moisture content of the feeds. Hence difference in particle sizes (diameters) leads to uneven drying this could be eliminated by sieving through screen to ensure equal particle sizes . Thus, equal drying will be guaranteed .

8.CONCLUSION

Gelatinization cassava marsh during drying becomes a critical period during drying or local frying. It is therefore imperative to avoid lump formation during gari processing. Hence in flash drying ,the problem of gelatinization posses difficulties in achieving fine products due to the lumps formation concomitant effect resulted in this phase of drying. During this phase , starch film enveloping the surface of the particle favours the sticking together of the particles during collision in the multi phased flow. In flash drying of this product ,a gelatinization chamber be design and developed as part of the flash dryer where after heat treatment at this chamber the preheated marsh will be discharge into the vertical pneumatic duct with a well-designed feeding mechanism. Also a low pressure channel can be adapted immediately below the feeding port to allow the particles directly under the influence of high speed scattering effect of the hot air stream. Turbulent flow can help to facilitate particles loosening and breakage during collision. These suggestions can help to improve flash drying of cassava marsh for fine particle products and eliminate the cost of acquiring milling machines and screens to process this product.

REFFERENCES

1. Ngoddy, P.O. 1976, Gari mechanization in Nigeria: the competition between intermediate and modern technology. In Appropriate Technology Problems and Promises, (Jaquier, E. ed) 1976, pp. 260-275.

2. Odigboh, E.U. 1978, Instruments for measurement of the thermal conductivity of solid food materials. Nigerian Journal of Engineering and Technology, Vol. 1, 1978, pp. 1 - 14.

3. Ibe. D.G. 1979,A partially mechanized village-scale gari production system. Proceedings of Nigerian Society of Agricultural Engineers, Vol. 3, 1979, pp. 223

4. Berenati RF and Brosilow CB 1962 Void fraction distribution in packed beds, *AIChE Journal*, **8**,
5. 359–361.

6. Brinkman HC 1947 A calculation of viscous force exerted by a flowing fluid on a dense swarm of particles, *Applied Science Research*, **1**, 27–34
7. Antonyuk, S., Khanal, M., Tomas, J., Heinrich, S., Mörl, L.: Impact breakage of spherical granules: experimental study and DEM simulation. Chem. Eng. Process. **45**, 838–856 (2006)

8. Hoomans, B.P.B., Kuipers, J.A.M., Briels, W.J., Swaaij, van W.P.M. (1996): Discrete particle simulation of bubble and slug formation in a two-dimensional gas-fluidised bed: a hard-sphere approach. Chem. Eng. Sci. **51**, 99–118

9. Huang, H., Dallimore, M.P., Pan, J., McCormick, P.G. (1998): An investigation of the effect of powder on the impact characteristics between a ball and a plate using free falling experiments. Mat. Sci. Eng. A **241**, 38–47

10. Hunter, S.C. (1956): Energy adsorbed by elastic waves during impact. J. Mech. Phys. Solids **5**, 162–171
11. Johnson, K.L. (1985): Contact Mechanics. Cambridge University Press, Cambridge

12. Plucknett, D.L. Ed., 1979 Small-Scale Processing and Storage of

Tropical root Crops, West view Tropical Agriculture Series, No.1, West view Press, Boulder, Colorado, 1979.

13. Darcy H 1856 *Les Fontaines Publiques de la ville de Dijon*, Dalmont, Paris.

14. David E, Lauriat G and Cheng P 1991 A numerical solution of variable porosity effects on natural convection in a packed sphere cavity, *ASME Journal of Heat Transfer*, **113**, 391–399.

15. Ergun S 1952 Fluid flow through packed column, *Chemical Engineering Progress*, **48**, 89–94.

16. Forchheimer P 1901 Wasserbewegung durch bodem, *Z. Ver. Deutsch. Ing.*, **45**, 1782.

17. Hsu CT and Cheng P 1990 Thermal dispersion in a porous medium, *International Journal of Heat and Mass Transfer*, **33**, 1587–1597.

18. Inaba H and Seki N 1981 An experimental study of transient heat transfer characteristics in a porous layer enclosed between two opposing vertical surfaces with different temperatures, *International Journal of Heat and Mass Transfer*, **24**, 1854–1857.

19. Kaviany M 1991 *Principles of Heat Transfer in Porous Media*, Springer-Verlag, New York.

20. Lauriat G and Prasad V 1989 Non-Darcian effects on natural convection in a vertical porous enclosure, *International Journal of Heat Mass Transfer*, **32**, 2135–2148.

21. Lewis RW and Ferguson WJ 1990 The effect of temperature and total gas pressure on the moisture content in a capillary porous body, *International Journal for Numerical Methods in Engineering*, **29**, 357–369.

22. Lewis RW, Morgan K and Johnson KH 1984 A finite element study of 2-D multi-phase flow with a particular reference to the five-spot problem, *Computer Methods in Applied Mechanics and Engineering*, **44**, 17–47.

23. Lewis RW, Morgan K, Pietlicki R and Smith TJ 1983 The application of adaptive mesh methods to petroleum reservoir simulation, *Revue de Institut Francais de Petrol*, **36**, 751–761.

24. Lewis RW, Roberts PJ and Schrefler BA 1989 Finite element modelling of two phase heat and fluid flow in deforming porous media, *Transport in Porous Media*, **4**, 319–334.

25. Lewis RW and Schrefler BA 1998 *The Finite Element Method in the Deformation and Consolidation of Porous Media*, John Wiley & Sons, Chichester.

26. Lewis RW and Sukirman Y 1993 Finite element modelling of three-phase flow in deforming saturated oil reservoirs, *International Journal for Numerical and Analytical Methods in Geomechanics*, **17**, 577–598.