doi: 10.17221/9/2013-RAE

Effect of speed, die sizes and moisture contents on durability of cassava pellet in pelletizer

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Abstract

Oduntan O.B., Koya O.A. (2015): **Effect of speed, die sizes and moisture contents on durability of cassava pellet in pelletizer**. Res. Agr. Eng., 61: 35–39.

The effect of pre-processing conditions such as speed, die sizes and moisture content on durability of cassava flour was investigated. Densification of cassava flour was done by pelletizing the flour through die and it is necessary to determine optimum conditions for designing and constructing a suitable processing plant. The flour was mixed with water at different blend ratios to form cassava mash of different moisture contents. The pellet quality was evaluated in terms of the durability of the pellets against the moisture content of the mash (18, 20 and 22% w.b.), die size (4, 6 and 8 mm) and the screw speed (90, 100 and 120 rpm). Test results showed that maximum durability of 84.437% was recorded at 20% (w.b.) moisture content using 4 mm die and low durability of 61.26% with using 8 mm die at 18% (w.b.) moisture content. The durability result shows that it decreased with increase in die size. Statistical analysis revealed that the die size had significant ($P \leq 0.05$) effect on the durability.

Keywords: cassava; pre-processing; densification; mash; screw speed

Global production of cassava tubers and the post-harvest processing activities have been on the increase in the last 20 years. The products from cassava tuber are prepared for human and animal consumption and industrial use, but with growing emphasis on animal consumption and industrial uses. Until recently, about 85% of the world production of cassava was consumed by man. The remaining 15% was shared between animal and chemical industries (Adeeko, Ajibola 1990). The development of alternative industry consumers of cassava may increase the value of this tuber crop, which are currently valued when used for human consumption.

The high cost and scarcity of some feed ingredients have been the most limiting factors for commercial livestock production in Nigeria coupled with man and animal competition for grains like maize. Formulated diet can be given to livestock to enhance growth and performance but the cost of producing the feed is quite expensive because of high cost of feed ingredients such as maize, wheat offal and corn-bran which are sources of energy. In order to reduce the cost of the feed, there are needs to look for alternative sources which are affordable and available.

Similarly to most other by-products from agro-processing, cassava are less-dense and therefore cannot be efficiently and economically transported over long distances to areas where they can be effectively utilized. Densification by pelletizing is one of the effective ways that has been used to increase the value of agricultural and biological materials (Barger 2003).

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Pellets are manufactured by grinding, conditioning and forcing the ground sample through dies that range in diameter from 2 to 10 mm or even larger (Oduntan et al. 2012). The physical quality of feed pellets is important for a number of reasons. First of all, transport and handling in both the factory and on the farm require pellets of certain integrity without fines produced by attrition stress. Pellets need to have a basic form of physical quality in terms of hardness and durability to withstand the rigors of transportation.

Research has shown that animals fed with good-quality pellets have better growth performance and feed conversion than those fed with mash, reground pellets, or pellets with more fines (Kertz et al. 1981; Brewer et al. 1989; Zatari et al. 1990). Behnke (1994) indicated that improvements in animal performance have been attributed to decreased feed wastage, reduced selective feeding, decreased ingredient segregation, less time and energy expended for prehension, destruction of pathogens, thermal modification of starch and protein, and improved palatability. Hardness is the force necessary to crush a pellet or a series of pellets at a time; durability is the amount of fines returning from pellets after being subjected to mechanical or pneumatic agitation (Thomas, van der Poel 1996).

Several laboratory methods have also been developed to measure the durability of pellets, namely: the tumbling box method, Holmen durability tester and Stokes hardness tester. The tumbling box method is the most popular method (Winowiski 1998) and an accepted standard in the feed industry. The correlation coefficients of the results from the tumbling box method and those from Young (1962) were 0.95 for pellets cooled for 24 h and 0.67 for hot pellets.

Several published studies have shown that moisture content and die sizes of the pellets are significantly affected by the durability of the pellets (Nelson 2002; McMullen et al. 2005; Fasina 2008). Therefore, the objective of this study was to quantify the effect of speed, die sizes and moisture content on durability of cassava flour.

MATERIALS AND METHOD

Sample preparation. Cassava tubers were obtained from a local farm in Ibadan, Nigeria. The tubers were washed, peeled with knife, grated and dried into cassava flour. Samples of the cassava flour were ground through a 0.5 mm screen using a disc mill (Model 206, Fexod disc mill; Fexod Fedek Venture, Ibadan, Nigeria). The moisture content of the cassava flour at the time of the experiment was determined using the oven method (ASTM 1995). The mixture was conditioned by adding water to the sample to raise the moisture from the initial value to the required level of 18, 20 and 22% (w.b.) for 10 min in a batch mixer (Fexod AS 170; Fexod Fedek Venture, Ibadan, Nigeria). The amount of water that was added was determined by the formula:

$$MC_{db} = [MC_{wb}/(100 - MC_{wb})] \times 100\% \quad (1)$$

$$m_w = (MC_{db} \times m_d)/100 \quad (2)$$

where:

MC_{db} – moisture content (dry basis) (%)

MC_{wb} – moisture content (wet basis) (%)

m_d – mass of dry matter (kg)

m_w – mass of water to be added (kg)

Experimental pelletizer. The pelletizer (Fig. 1) is basically a combination of an auger and a die. The die serves as a back plate for retaining the pressure exerted by the auger, whilst the perforations in the die allow the compressed mash wriggle out to form pellets. The die was to simulate the pellets extrusion by using holes (4, 6 and 8 mm) in real scale. A helical auger is mounted on a tapering shaft which is supported on bearings so that the shaft rotates freely in the stationary cylindrical barrel.

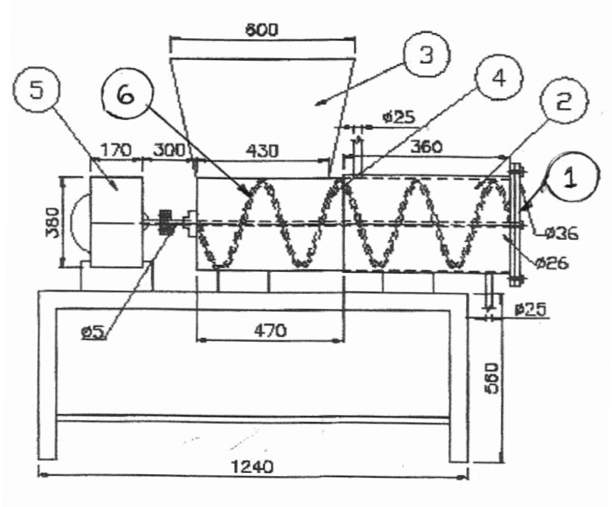

Fig. 1. Orthographic drawing of machine
1 – die plate; 2 – heat exchanger barrel; 3 – hopper; 4 – main barrel; 5 – gear box; 6 – screw

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Cassava mash is introduced into auger through the inlet gate of the barrel. The auger conveys the mash to the die and builds up pressure for its extrusion. Pressure resulting from rotating auger forces the mash through the perforations in the die, compressing and forming it into pellets. The pellets were allowed to break off by force of gravity, so that sizing was random, but excessively long particles are likely to be readily broken during handling.

The pelletizer consists of the following parts: barrel, shaft on which the auger is welded, hopper, heat exchanger barrel, reduction gear and frame. Each component was designed following the standard engineering principles (Oduntan et al. 2012). The resulting mash was compressed by the pelletizer at different screw speed (90, 100 and 120 rpm) for pelleting operation. This die offers a better way to reproduce the pellets.

Durability test. The durability (D_u) of the pellets was determined according to ASABE S269.4 (2003) standard. A 100 g sample of the pellet was tumbled at 50 rpm for 10 min in a dust tight enclose (Engineering Laboratory Equipment, London, UK). Based on the standard, moisture content of samples should be about 11% and length of them should be three times their diameter. Sieves with 3, 5, and 7 mm apertures were used for the pellets extruded from the 4, 6 and 8 mm dies, respectively. Durability was expressed as the percent ratio of the mass of pellets retained on the sieve after tumbling to mass of pellet before tumbling. Durability is said to be high when the measured value is above 80%, medium when between 70 and 80% and low when below 70% (Colley et al. 2006):

$$D_u = (M_{pa}/M_{pb}) \times 100\% \quad (3)$$

where:

M_{pa} – mass of pellet after tumbling (kg)

M_{pb} – mass of pellet before tumbling (kg)

D_u – durability of pellet (%)

All measurements were carried out in triplicate. Statistical analysis and equation fitting using appropriate procedures in SAS statistical software package (SAS 2005, Institute Inc., Cary, USA) were performed on all data.

RESULTS AND DISCUSSION

A summary of the average durability of the cassava pellet at different processing conditions (speed, die size and moisture content) is presented in Table 1. The result indicates that the durability decreases with increase in die sizes for all moisture content variation at different speed conditions. The mean values of durability of the pellet lie between 61.26 and 84.437%. This value is higher than values obtained for durability of barley pellet conditioned at 70°C using 5 mm die size (McMullen et al. 2005), but lower than values for barley pellet conditioned at 90°C using 5 mm die size (Thomas, van der Poel 1996), alfalfa pellet (Fasina, Sokhansanj 1995), switchgrass pellet (Colley 2006) and peanut hull pellets (Fasina 2008).

Table 1. Durability of the cassava pellet (%) at different pre-processing conditions

Speed (rpm)	Die size (mm)	Moisture content (%)		
		18	20	22
90	4	79.88(1.34)	83.84(2.42)	81.67(1.17)
	6	76.25(0.98)	76.79(1.99)	75.54(0.58)
	8	61.26(1.01)	64.8(2.19)	64.57(0.79)
100	4	78.07(1.71)	81.67(2.42)	82.57(2.18)
	6	77.17(0.74)	74.93(0.96)	74.20(1.88)
	8	62.88(1.21)	61.67(1.22)	65.54(2.58)
120	4	80.83(1.10)	84.43(1.45)	65.54(1.57)
	6	76.75(0.35)	78.87(1.89)	74.74(0.62)
	8	65.37(1.95)	65.43(1.38)	61.46(1.78)

values are means of triplicate and numbers in parentheses are standard deviation

Generally, pellet with large diameters are more liable to breakage than those of the smaller diameter as they fall off from the die plate. It appears reasonable since a max. durability of 84.437% was recorded at 20% (w.b.) moisture content using 4 mm die and low durability of 61.26% with using 8 mm die at 18% (w.b.) moisture content.

The durability result shows that it decreased with increase in die size as in Fig. 2. The results indicate the binding forces in small size pellets strengthened the bond between individual particles in the pellets. Statistical analysis of these results is presented in Tables 2 and 3. Statistical analysis revealed that the die size die size had significant ($P \leq 0.05$) effect on the durability of the pellet ($F_{2.54} = 326.99$). As reported earlier, the durability of the pellets is significantly affected by moisture content (Nelson 2002; McMullen et al. 2005; Fasina 2008); it is thus interesting to note that the speed and mois-

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Table 2. Summary of ANOVA on the effects of speed, MC and die on cassava pellet durability

Source	DF	Sum of square	Mean square	*F*-value	*Pr* > *F*
Die	2	4,640.27	2,320.14	326.99	< 0.0001
Speed	2	7.92	3.96	0.56	0.5757
Die × speed	4	15.63	3.91	0.55	0.6993
MC	2	0.05	0.02	0	0.9963
Die × MC	4	22.89	5.72	0.81	0.5263
Speed × MC	4	11.08	2.77	0.39	0.8146
Die × speed × MC	8	34.44	4.31	0.61	0.7682
Error	54				

DF – degrees of freedom; *F* – ratio of mean square to error mean square; *Pr* – value associate with *F*-statistic; MC – moisture content

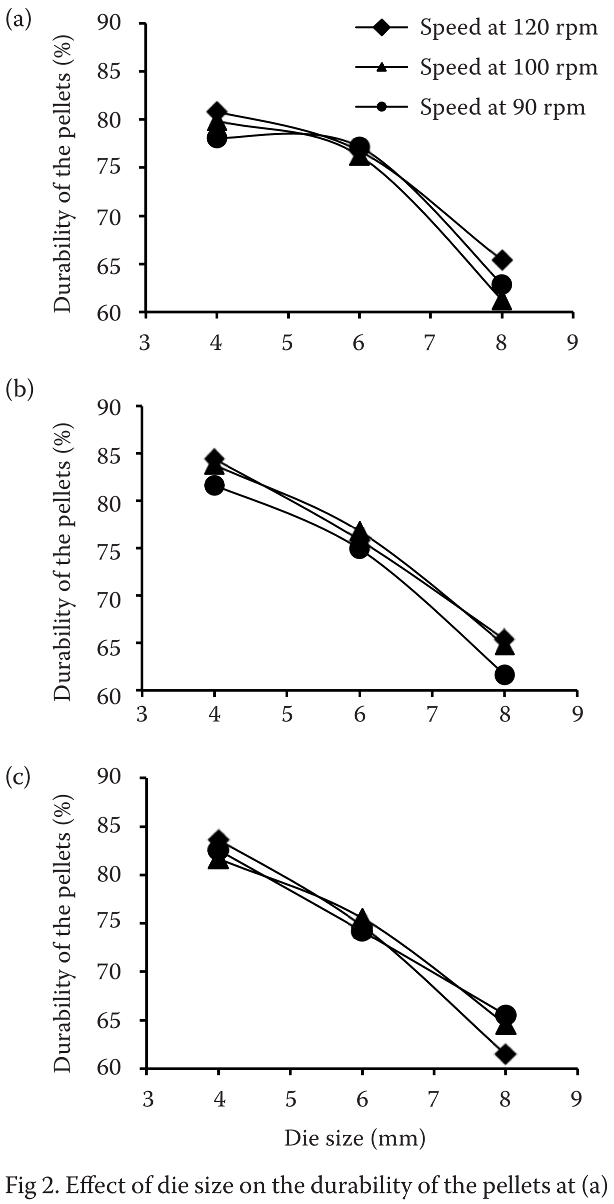

Fig 2. Effect of die size on the durability of the pellets at (a) 18%, (b) 20% and (c) 22% moisture content (w.b.) pelletized at various speeds and die sizes

Table 3. Summary of the Duncan's multiple range tests on main effects (speed, moisture content and die) on cassava pellet durability

Description	Factors	Durability (%)
	90 rpm	73.84[a]
Speed	100 rpm	73.36[a]
	120 rpm	74.11[a]
	18%	73.69[a]
MC	20%	73.81[a]
	22%	73.76[a]
	4 mm	81.87[a]
Die	6 mm	75.79[b]
	8 mm	63.66[c]

values with the same superscript in the column are not significantly different at ($P \leq 0.05$) according to the Duncan's multiple range test; MC – moisture content

ture content do not significantly affect the durability when the moisture content of the mash is low or high and likewise the speed, too. This could be attributed to the fact that higher heat generated in the barrel due to the small hole (4 mm) may imply a higher level of starch gelatinization in the pellet. Hence, it is not surprising that the interaction of the effect of the die size was significant on the durability (Table 2). This relation could be part of the explanation for the improved pellet quality in the pellet size (4 mm).

CONCLUSION

– The significant factors affecting durability of cassava pellets under different pre-conditions

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were investigated. Cassava flour under different pre-processing conditions exhibited that the durability of pellets decreased while the moisture content increased significantly ($P \leq 0.05$) and separately with increasing die size and moisture content of cassava mash.
- The best durable pellet was obtained using 4 mm die at 20% (w.b.) moisture content of and least durable using 8 mm die at 18% (w.b.) moisture content.
- Die size affects pellet quality with the use of the pelletizer at different pre-conditions.

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Received for publication January 27, 2013
Accepted after corrections June 7, 2013

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