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Full Length Research Paper

Effects of processing conditions on the hardness of cassava pellets

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In this study, an experimental rig attached to a Testometrics Universal Testing machine for the purpose of extrusion was used to investigate the effects of processing conditions on hardness property of cassava pellets. The parameters considered were machine speeds of 1.5, 2.5, 3.5, 4.5 mm/min, die diameters of 6, 8, 10, 12 mm and cassava dough of moisture content levels 48.5, 50.5, 52.5 and 54.5%w.b. Result of the statistical analysis of variance showed that all the parameters and their interactions were significant on hardness property of cassava pellets at 5% level. Further analysis by Duncan's Multiple Range Test reveals that hardness increased with increase in the process condition. Quality pellets can be obtained when cassava dough is conditioned into moisture contents level of above 45.5%w.b and below moisture content level 45.5%w.b.

Key words: Hardness, pellets, cassava.

INTRODUCTION

Cassava is a root crop that has bearing upon the lives of millions in the developing countries. Cassava roots now compete with other carbohydrate sources, especially maize and sorghum, on the basis of price, nutritional value, quality and availability. Cassava suffers from post harvest physiological deterioration once it is harvested, the fresh harvested cassava deteriorates rapidly, thus within 48 h it is unmarketable. Another drawback of cassava is that there are severe crop losses because of viral or bacterial diseases (Nweke et al., 1999). With the expansion of the European Union to Eastern European countries, the demand for cheap carbohydrates has substantially gone up. In addition, there is growing demand in South Korea, Russia, Israel that can reach up to 4 million tonnes over the next decade. Therefore, there is need for the production of cassava pelleting machines in Nigeria for the production of cassava pellets in order to reduce losses and meet up with the international demands for cheap carbonhydrates

The main objective of this research work is to investigate the effect of some machine parameters and moisture content of preparation of cassava dough on the hardness property of cassava pellets.

The specific objective is to determine the effect of the speed of the machine, die diameter of the extrusion rig, and moisture content of preparation of the cassava dough on the hardness of cassava pellet.

Pelleting involves the feeding in of material, compression maintaining it under pressure and ejection of pellets (Bellinger and McColly, 1961). Pelleting can be defined as moulding and compressing of materials of powdery, flaky and bulky structures into pellets.

Generally the material to be pelletized is first ground in the mill, then mixed with other materials to obtain the desired ration, after which the mixture is pelleted with the addition of water or preferably steam to aid in the pelleting process. The pellets are then dried and cooled to dissipate the heat, some of which came from the steam and some from wasted energy in the pelleting process (Bruhn, 1957). A basic method for producing the volume of forage and granular- farinaceous fodder is pelleting. Handling of pelleted material is simple and in the case of fodder mixtures the risk of separation of individual component prevented (Sitkey et al., 1986).

The main mechanical means of production of pellets are through extraction in a special pelletizing mill or using a screw extruder to convey the material for extrusion. In both cases, the moist plastic mixture is forced through the

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holes of a die. The function of material pushed through the holes provides the mechanical resistance that is needed for obtaining compaction; adjustable blades which are rod like extracted materials into segment of the desired length.

Overall, it has been realized that fine grinding produces denser pellets and increase the output capacity of machines as the materials passes the machine more easily therefore, it is often recommended that the length of the chop be one half the diameter of the pellet being produced (Dobie, 1959). Sokhansanj et al. (1991), found that grind from high quality chop had greater compressibility and produced a pellet with a higher tensile strength relative to lower quality chop.

MATERIALS AND METHODS

The materials used for this experiment are classified into two groups namely: the cassava powder and the mechanical extrusion rig.

The cassava tuber used in the processing of cassava powder was bought from Idofian market in Ifelodun Local Government area of Kwara State. The tubers were processed according to Nweke (1988), by peeling using local knives. They were then washed to remove the dirt and chipped with the aid of the cassava chipping machine available at National Centre for Agric. Mechanization Central Workshop. The chips were dried using the NCAM batch drier and milled into powder using the NCAM dry-milling machine. The mechanical extrusion process involves the application of a compressive force on the cassava material enclosed in a cylinder with replaceable die. This extrusion process was mounted on the Testometrics Universal Testing Machine (Model M500 50KN) as shown in Plate 1.

The mechanical extrusion rig is an existing rig attached to the Universal Testing Machine in the Engineering Material Testing Laboratory.

Hardness measurement

This is the measure of the strength of the pellets. A Monsanto Tensometer machine was used to determine the hardness of the cassava pellet. This was achieved by holding the pellet in between the spherically mounted nose piece after the mercury column that is graduated from 0 to 30 N had been adjusted to zero point and the driven gear box was operated manually to apply force by moving the spherically mounted nose piece closer to each other, the mercury column advanced and stop at the point of crack on the pellet. The force applied was read from the scale attached to the mercury column.

RESULTS

The Analysis of Variance (ANOVA) Table for hardness on speed, moisture content and die diameter as main factors as well as all possible interactions is as shown in Table 1. From Table 1, it can be seen that moisture content of the cassava dough, speed of the machine and the die diameter of the extrusion rig as well as all the interactions between them were significant at 5 percent level. This shows that the process conditions and all their interactions had effect on hardness.

Plate 1. The Piston-Cylinder assembly on the Universal Testing Machine.

Effect of moisture content on hardness

From Table 1, it is seen that the moisture content of cassava dough had significant effect on the hardness of cassava pellets at 5% level. Using the Duncan's Multiple Range Test, the levels of the moisture content that led to the significant difference in the hardness of cassava pellets were determined as shown in Table 2.

From this table, it is seen that the mean values of hardness at various level moisture content are all significantly different from each other at 5% level. The moisture content level 50.5%w.b had the highest hardness mean value followed by 48.5%w.b, while the least hardness mean value is at moisture content of 54.5%w.b, the highest mean value of hardness at 50.5%w.b was due to the attraction force which is caused by the Vander Waal's electrostatic or magnetic force. This is high because of the high area of contact between the particles of the pellet produced compared to the area of contact between the pellets produced at moisture content levels 48.5%w.b which had a low magnetic force due to small quantity of moisture added.

Nevertheless, as for the moisture content level 54.5%w.b, the binding force is so loose and the area of contact is highly affected due to high quantity of moisture added.

Table 1. Analysis of variance table (anova) for hardness.

Source	SS	Df	M.Square	F-value.	F-Prob
Corrected model	7561.947	63	120.031	14.375	*<0.0001
Intercept	23023.470	1	23023.470	2757.216	*<0.0001
MD	3068.848	3	1022.949	122.505	*<0.0001
S	293.327	3	97776	11.709	*<0.0001
D	255.827	3	85.276	10.212	*<0.0001
MD * S	316.960	9	35.218	4.218	*<0.0001
MD * D	950.293	9	105.88	12.645	*<0.0001
S * D	477.897	9	53.100	6.359	*<0.0001
MD * S * D	2198.796	27	81.437	9.753	*<0.0001
Error	1068.833	128	8.350		
Total	31654.250	192			

*Significant at 5% level.
MD = Moisture Content, S = Speed, D = Die Diameter.

Table 2. Effect of moisture content on hardness.

Moisture content (%w.b)	Mean hardness (kg/mm^{2})
48.5	13.85 ^{A}
50.5	15.21 ^{B}
52.5	9.7 ^{C}
54.5	4.95 ^{D}

Means with the same letters are not significantly different at 5% level using Duncan's multiple range test.

Table 3. Effect of speed on hardness.

Speed (mm/min)	Mean
1.5	9.27 ^{A}
2.5	10.83 ^{B}
3.5	10.94 ^{B}
4.5	12.74 ^{c}

Means with the same letters are not significantly different at 5% level using Duncan's Multiple range test.

Effect of speed on hardness of cassava pellet

From Table 1, it can be seen that speed of the machine had significant effect on the hardness of the cassava pellet at 5% level. The level of the speed of the machine that contributed to this significant effect on the hardness of the cassava pellet was determined using Duncan's Multiple Range Test was employed which is as shown in Table 3.

From the Table, it was observed that the mean value of hardness was high at speed level 4.5 mm/min, which is the highest speed. It was also observed that speed levels 3.5 and 2.5 mm/min were not significantly different from each other at 5% level. This means they both had similar effect on the hardness of cassava pellets. Moreover, the least mean value of hardness was at speed level 1.5 mm/min and it is significantly different from all other speed levels at 5% level. Thus, the mean value of hardness that is at the highest speed level 4.5 mm/min is contrary to the recommendation of Hills and Pulkinen (1996) but in line with the conclusion of Heinemans (1991). This might be as a result of high collision rate within the particles of the cassava dough which increase the magnetic force thus, increase the binding force within the particles thereby increases the hardness of the cassava pellet produced.

Table 4. Effect of die diameter on hardness.

Die diameter (mm)	Mean hardness (kg/mm^{2})
6	12.40 ^{A}
8	11.77 ^{A}
10	9.79 ^{B}
12	9.84 ^{B}

Means with the same letters are not significantly different at 5% level using Duncan's multiple range test.

Effect of die diameter on hardness

From Table 1, it can be seen that die diameter had significant effect on the hardness of cassava pellet at 5% level to each other using Duncan's Multiple Range Test. The levels of the die diameter that really contributed to the significant effect on hardness of the pellet are as shown in Table 4.

From this table, it is seen that die diameter 6 mm had the highest mean value of hardness followed by 8 mm, then 12 mm and die diameter 10 mm had the least mean value of hardness. However, the mean values of hardness for die diameters 6 and 8 mm are not significantly different from one another at 5% level, likewise die diameter 10 and 12 mm are not significantly different. Thus, the highest mean value of hardness which is at die

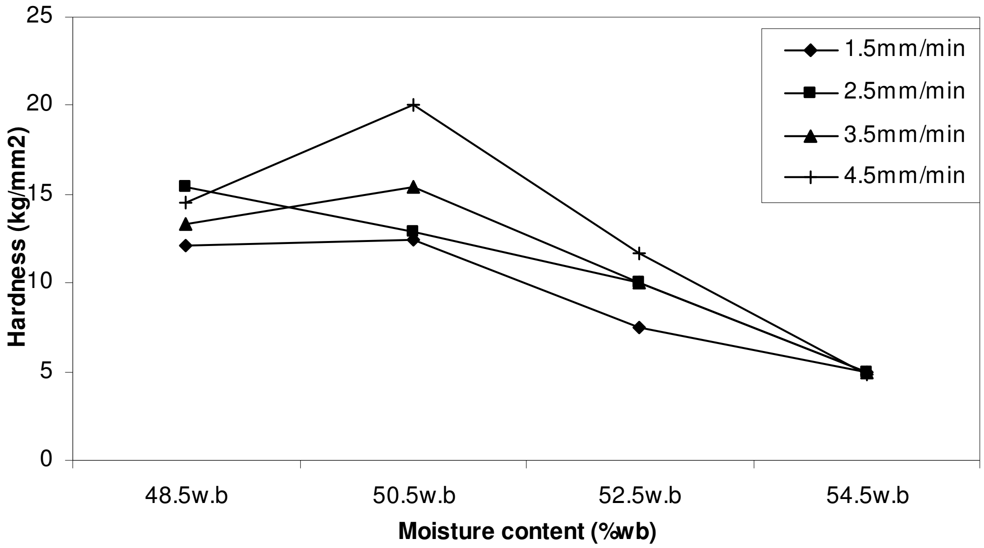

Figure 1. Effect of moisture content on hardness at different speed levels.

diameter 6 mm might be as a result of the high compressive force exerted on the cassava dough when extruding through the smaller die.

Effect of moisture content on hardness at different speed level

From Table 1, it can be seen that the interaction between moisture content and speed had significant effect on the hardness of cassava pellets at 5 % level. The effect of this interaction is shown in Figure 1.

From Figure 1, it was observed that there was an initial increase in trend of hardness of cassava pellets with increase in moisture content of pellets produce at speed 1.5, 3.5 and Speed 4.5 mm/min. But speed 2.5 mm/min had initial decrease with increase in the moisture content. The first three levels of speed had their peak at moisture content level 50.5% (w.b) which gradually decreased as the moisture content level increase. The reason for this is that it was observed that moisture is being pressed out along with the pellets produced as the piston moved in the cylinder leaving a caked, dried cassava dough sample in the cylinder that could not be pelletized. This was also experienced by Tabil et al. (1997). It may be deduced from this result that as the speed increases, the binding force within the particles of the cassava dough also increases, there by increasing the area of contact which brings about the formation of the caked cassava dough.

Effect of speed on hardness at different die diameter

From Table 1, it can be seen that the interaction between the speed and die diameter had significant effect on the hardness of cassava pellets. The effect of this interaction is as shown in Figure 2.

From Figure 2, it was seen that hardness of cassava pellets produces from die diameter levels of 6, 10 and 12 mm had an initial trend of increasing in hardness as the speed increases later decreases, while 12 mm, finally increased as the speed increases. But die diameter levels 6 and 10 mm increase as the speed increases. This supported the conclusion stated by Heinemann's (1991) that die speed can be used as a basis of obtaining high quality pellet, the higher the speed, the higher the hardness and the higher the die diameter, the higher the area of contact due to increase in the collusion rate among the particles of the cassava dough.

Effect of die diameter on hardness at different moisture level

From Table 1, it can be seen that the interaction between die diameter and moisture content is significant at 5% level. The effect of this interaction is as shown in Figure 3.

From Figure 3, it was seen that there were trends of decrease in hardness of cassava pellets formed from moisture content levels of 48.50 and 50.50%w.b. Moisture content level 54.5%w.b had initial decrease as the die diameter increases from the smaller die diameter. While others increased along the line, moisture content level 50.5%w.b decreased, but later increased and gave the highest hardness with the highest die diameter, while others decreased. But moisture content level 54.59%w.b decreased linearly as the die diameter increased. From the above, it can be deduced that the higher the moisture contents in the cassava dough, the lower the hardness.

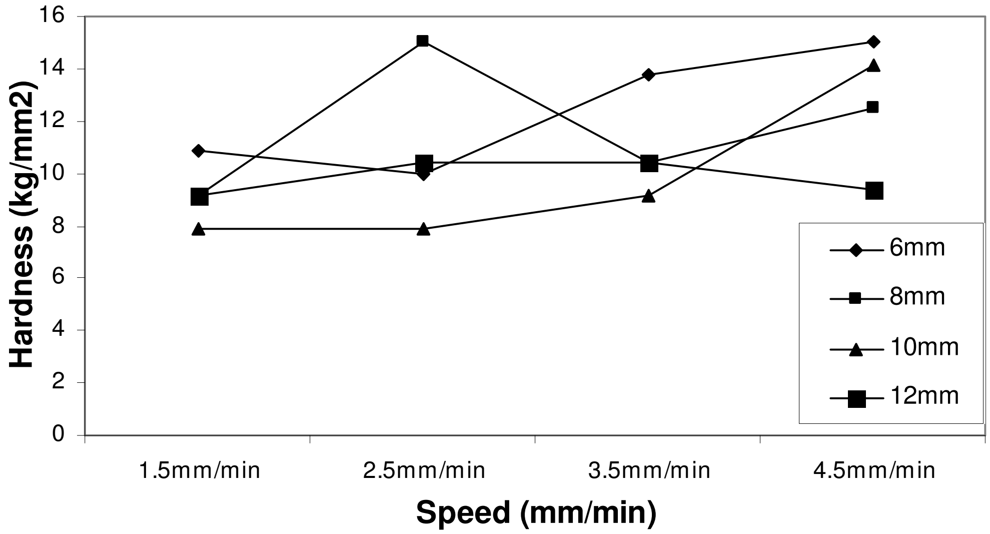

Figure 2. Effect of speed on hardness at different die diameter.

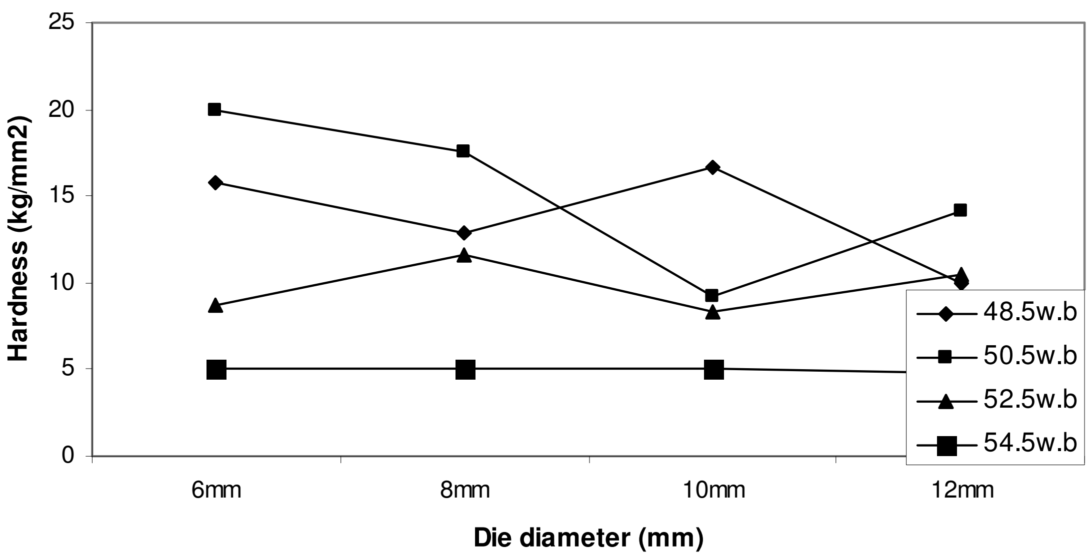

Figure 3. Effect of die diameter on hardness at different moisture content level.

This may be due to the decrease in the area of contact within the particles of the cassava.

Conclusion

Based on the results presented in this work, the following conclusions can be made:

i). Cassava dough can be successfully used to obtain cassava pellets.
ii). In pelletizing cassava products, quality cassava pellets can be obtained at moisture content levels of above 48.5% w.b and below 55.5%w.b with die diameters ranges from 6 to 12 mm.
iii) At higher machine speed level 4.5 mm/min, lower die diameter produced quality cassava pellets. Also at speed level 1.5 mm/min, higher die diameter produces quality cassava pellets.
iv) Increase in moisture content of cassava dough increases the quality of cassava pellets.

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