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EFFECT OF PROCESSING CONDITIONS ON THE BULK DENSITY OF CASSAVA PELLETS

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ABSTRACT

In this study, an experimental rig attached to a TESTOMETRIC Universal Testing Machine for the purpose of extrusion was used to investigate the effects of some machine parameters and the moisture content of preparation of cassava dough on some physical and mechanical properties of cassava pellets. The parameters considered were machine speeds of 1.5mm/min, 2.5mm/min, 3.5mm/min, 4.5mm/min, die diameters of 6mm, 8mm, 10mm, 12mm and cassava dough of moisture content levels 48.5%wb, 50.5%wb, 52.5%wb and 54.5%wb and their effects on the Bulk density of cassava pellets.
Result of the Statistical Analysis of Variance showed that all the parameters and their interactions were significant on most of the properties of cassava pellets at 5% level. Further analysis by Duncan's Multiple Range Test reveals that Bulk density increased with increase in the process condition and level . Quality pellets can be obtained when cassava dough is conditioned into moisture contents level of above 45.5%wb and below moisture content level 55.5%. The study shows that cassava dough can successfully be used to obtain quality cassava pellets.

Key words: Cassava, pellets, Bulk density, die diameter, moisture content

1. INTRODUCTION

Cassava is a crop which tolerates drought and low fertility and is primarily grown by small scale farmers in area with marginal soils or unfavorable climates. It has the ability to withstand poor environmental condition.(Nweke *et,al. 2000)*
According to the report of a FAO consultancy in Africa, the majority of cassava is human consumption and non-food use starches accounts for about 75% of the output of commercial starch industry. The growth of the starch industry in the future appears to be very promising provided the quality of products and the development of the new products permit them to compete with the various substitutes.. One of the major problems associated with cassava is the rapid post-harvest deterioration, which renders it unpalatable as food (Akinoso and Kasali, 2012). It is full of carbohydrates and very little protein. On digestion, carcinogenic glucosides present in the root are broken down and cyanide can be released into the body system. These can be removed by washing the cassava in clean water or by fermentation (Nweke *et al* 2000).
It is estimated that 40% of the cassava produced in Nigeria is lost due to lack of processing capacity and market outlet.(Nweke *et al* 2000).Also, commercial production of cassava pellets will bring about rapid socio economic transformation, which will raise the standard of living of many rural dwellers. Job opportunities will be created for rural people. They will be encouraged to farm knowing that their efforts would be rewarded in market.

The main objective of this research work is to investigate the effect of some machine parameters and moisture content of cassava dough on bulk density properties of cassava pellets. The specific objective is to determine the effect of the speed of the machine, die diameter the extrusion rig and moisture content of preparation on bulk density of cassava pellet.

1.1 PELLETING

Pelleting can be defined as moldings and compressing of materials of powdery, flaky and bulky structures into pellets. Pellets can also be define as a densified, cylindrical fuel, which is obtained by pressing the material through the holes in a die. The change in the bulk density and achievement of an exact particle size are the reasons for pelletization.

The density and durability of pellets fabricated under a given pressure, depends on numerous factors, the most important of which are the material's structure, temperature, initial volumetric weight and moisture content, the velocity of pelleting and the duration for which pressure is maintained. With increasing moisture content, many agricultural materials assume plastic properties, facilitating compression. Thus a given volumetric weight relative to the dry content can generally be attained only by higher pressure if the moisture content is higher (Sitkey.et al. 1986).

Singh and Singh (1982) reported that pellets made by using molasses as binder has the highest combustion efficiency of 70.1% followed by that of mixture of sodium silicate and molasses, 45.3% and then by that of sodium silicate, 34.8%. But the maximum bulk density and durability of pellet was observed when sodium silicate was used as the binder at $30N/mm^2$. This is because sodium silicate has a good binding characteristic but poor combustion property as compared to others. Also the quality of binder is another factor, the bulk density and durability increases with increase in quantity of binder.

According to Samson et al. (2000), a number of studies have examined the impact of the length of chop on the pellet process. Overall, it has been realized that fine grinding produces denser pellets and increase the throughput capacity of machines as the materials passes the machine more easily (Dobie 1959).

Pressure is one of the many factors affecting the formation of pellets. Oyeyemi (1991), reported several works that had been done on the feasibility of compacting agricultural waste into blocks of compressed material under pressure. He reported that the pressure required to form a briquette increased exponentially with both briquette relaxed density and die diameter. The specific energy required increased linearly with relaxed density .It was further explained that a relationship between pressure and density shows on removing pellets from die, it showed both elastic recovery and stress relaxation process occur in a creep test when the load is removed and instantaneously the elastic deformation is recovered fully while relaxation described the condition of the material under constant deformation when the material under constant deformation when the stress decrease continuously with time.

Different modes of mechanical loading had no practical advantage on the pellets formed. The period of time a pellet was subjected to pressing can increase the relaxed pellet density slightly but the times were too long for practical application.

Also according to Oravainen (1983), the pelletizing process of straw and peat with mobile pelletizing plant are also described. This is such that a mobile pelletizing plant is employed. Here the production of pellets takes place near the raw material, the fuel properties of pelletized peat and straw obtained do not differ from the properties of the raw material except in terms of moisture content and bulk density. Although the temperature rises during the pressing phase to as much as 100ºC there are no changes in the composition of the fuel.

2.0 Experimental 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 tubers used in the processing of cassava powder were bought from Idofian market in Ifelodun Local Government area of Kwara State. The tubers were processed by peeling using local knives, then washed to remove the dirt and chipped with the aid of the cassava chipping machine available at National Centre for Agric. Mechanization Central (NCAM) Workshop Idofian in Kwara state. The chips were dried using the NCAM batch drier and milled into powder using the NCAM dry-milling machine.

2.1 Mechanical Extrusion Rig.

The mechanical extrusion process involves the application of a compressive force on the cassava material enclosed in a cylinder with replaceable die. This extrusion rig was mounted on the TESTOMETRICS Universal Testing Machine (Model M500 50kg) as shown in Figure 1

Figure .1: Showing the Piston-Cylinder assembly on the Universal Testing Machine.

2.2 Bulk density measurement

The bulk density is the mass of group of individual pellets divided by the space the entire mass occupied including the air space. The bulk density of the cassava pellet was measured using a cylindrical container 300mm in diameter and 310mm high (ASAE Standards 2002).

3. RESULTS AND DISCUSSIONS

From Table 1, it was seen that the moisture content of cassava dough, the speed of the machine and the die diameter of the extrusion rig as well as all their interactions were significant at 5 percent level. This shows that all the processing conditions and their combinations had effect on bulk density of the cassava pellets

Table 1: **ANALYSIS OF VARIANCE TABLE (ANOVA) FOR BULK DENSITY.**

Source	Sum of Squares	Df	Mean Square	F-value	F-Prob.
Corrected Model	6697.136	63	106.304	5.772	*<0.0001
Intercept	622197.90	1	622197.90	33785.373	*<0.0001
MD	1458.983	3	486.328	26.408	*<0.0001
S	422.608	3	140.869	7.649	*<0.0001
D	1413.122	3	471.041	25.578	*<0.08001
MD * S	923.164	9	102.574	5.570	*<0.0001
MD * D	756.549	9	84.061	4.565	*<0.0001
S * D	550.270	9	61.141	3.320	*<0.0001
MD * S * D	1172.439	27	4.424	2.358	*<0.0001
Error	2357.273	128	18.416		
Total	631252.31	192			

*Significant at 5% level.

MD=Moisture content, S=speed, D=Die diamete

Effect of Moisture Content on Bulk density

From table 1, it is seen that the moisture content of cassava dough had significant effect on the bulk density of cassava pellets at 5 percent level.

In order to kwon the levels of the moisture content that led to this effect, Duncan`s Multiple Range Test was applied and this is as shown in Table 2.

From table 2, it shows that the moisture content 54.5%wb had the highest mean value of bulk density while the moisture content 48.5%wb had the least mean value of bulk density. Moreover, moisture content level 50.5%wb and 52.5%wb are not significantly different from each other which show that these moisture levels had similar effects on the bulk density of cassava pellets produced. For the highest mean value of bulk density to be at the highest moisture content level of 54.5%wb, this might be as a result of the increase in the binding force between the particles of the cassava dough that resulted in the formation of the caked, dried cassava dough sample left behind in the cylinder cage after which moisture has been pressed out. This reduced the moisture content level and probably increased the bulk density of the pellets.

Effect of die diameter on bulk density

From Table 1, it was seen that die diameter of the extrusion rig had significant effect on the bulk density of cassava pellets produced at 5% level.

In order to know the levels of die diameter that contributed to the significant effect on the bulk density of cassava pellets produced, Duncan´s Multiple Range Test was used and the mean values of the bulk density are as shown in table 3.

From Table 3, it is seen that die diameter 8mm had the highest mean value of bulk density followed by 6mm then 10mm and the least bulk density is at 12mm.Both die diameters 6mm and8mm are not significantly different from each other at 5% level likewise die diameter 10mm and 12mm, they are not significantly different from each other too but the pairs are significantly different from each other at 5% level.

From the above observation, it is noted that at high levels of die diameter, bulk densities are low, while they are high at die diameters that are low. This might be as a result of a good deal of air being expelled during compression through the larger die.

Table 2 Effect of moisture content on bulk density

Moisture Content (%wb)	Mean Bulk density
48.5	54.18 [A]
50.5	55.65 [B]
52.5	56.37 [B]
54.5	61.50 [C]

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

Table 3 Effect of Die diameter on bulk density

Die diameter	Mean bulk density
6mm	59.12 [A]
8mm	60.10 [A]
10mm	54.46 [B]
12mm	54.02 [B]

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

From Table 1 , it is seen that the speed of the machine had significant effect on the bulk density of cassava pellets at 5% level.

In order to know to the levels of the speed that contributed to the effects, Duncan's Multiple Range Test was used and the summary of the mean values of the bulk density is as shown in Table 4.

The table indicates that the highest mean value of bulk density was at speed level of 3.5mm/min followed by 2.5mm/min and then 1.5mm/min. The lowest mean value of bulk density is at the highest speed level of 4.5mm/min. Mean values of bulk density, at speed levels 3.5mm/min, 2.5mm/min and 1.5mm/min, are not significantly different from each other at 5% level, showing that the three speed levels had similar effect on the cassava pellets produced. The highest speed level of 4.5mm/ min had a distinct effect from the other three speeds.

From speed levels 1.5mm/min to 3.5mm/min, the mean values of bulk density increased and later decreased as the speed advanced to speed level 4.5mm/min. This might be as a result of high collision forces generated between the particles of the dough as the speed increased but the collusion forces might be slowed down at the highest speed since it was observed that at the highest speed, the quantities of the caked, dried cassava sample left behind in die end of the extrusion rig increases.

Table 4. Effect of Speed on Bulk density

Speed mm|min	Bulk density
1.5	57.06 ^{A}
2.5	57.65 ^{A}
3.5	58.49 ^{A}
4.5	54.51 ^{B}

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

Effects of Moisture Content on Bulk density at Different Speed Levels

From table 1, it is seen that the interaction between the moisture content of the cassava dough and the speed of the machine had significant effect on the bulk density of the cassava pellets at 5% level and this is as shown in Figure 1.

From Figure 1, it can be observed that there was an initial increase in the trend of bulk density as moisture content increase for speed levels 1.5mm/min, 2.5mm/min and 4.5mm/min. They all had their peak at moisture content of 50.50%wb and later speed 1.5mm/min and speed 4.5mm/min both decreased down as the moisture content increases further, while speed level 2.5mm/min which had an initial decrease in the trend of the bulk density and speed level 3.5mm/min increases down as the moisture content increases. This might be as a result of the moisture content levels in the cassava dough which has a greater impact on the binding force which has a lot to do with the surface contact.

Effect of die diameter on bulk density at different moisture content levels

From Table 1, it is seen that the interaction between the die diameter of the rig and the moisture content of the cassava dough is significant on the bulk density of cassava pellets produced at 5% level and it is as shown in Figure 2.

From Figure 2, it can be seen that, from the four levels of moisture content, the bulk densities of pellets between moisture levels 48.50%wb and 52.50%wb decrease as the die diameter increase and the bulk densities of pellet from moisture content level 54.50%wb has initial increasing trend as the die diameters increase and later decrease as die diameter increases while the bulk density of pellets from the moisture content level 50.50%wb has initial increase in the trend as the die diameter increase and finally decrease as the die diameter increase. Due to the great effect that moisture content has on the die diameter of the extrusion rig, the above observation might be as a result of this effect which also has to do with the binding force within the particles of the cassava dough. From literature, bulk density is among the factors that determine the quality of cassava pellets and it is noted that the die diameter of the machine has great effect and also plays an important role in the designing of a cassava pelleting machine.

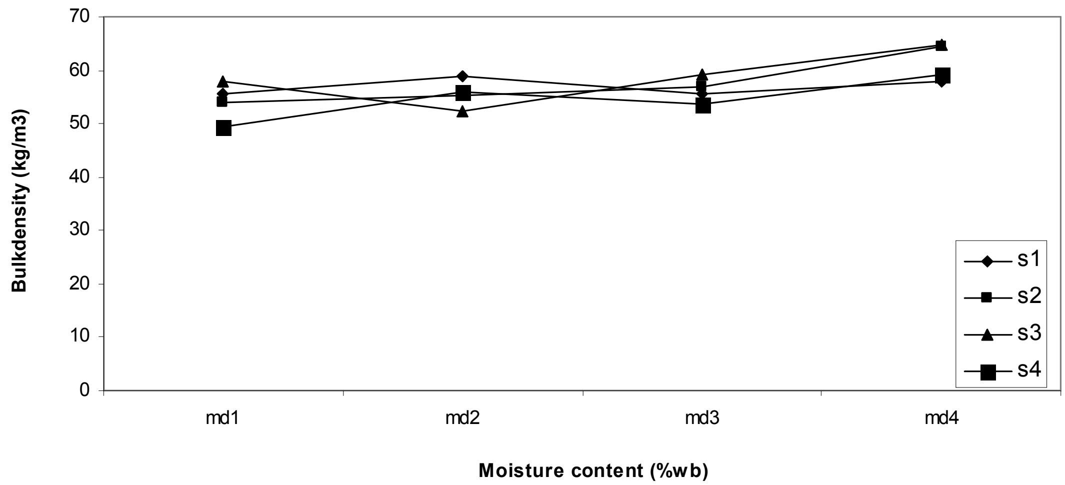

Figure 2: Effect of moisture content on Bulk density at different speed levels.
Legend: S1=1.5mm|min, S2=2.5mm|min, S3=3.5mm|min, S4=4.5mm|min
Md1=48.5%(wb), Md2=50.5%(wb), Md3=52.5%(wb), Md4=54.5%(wb)

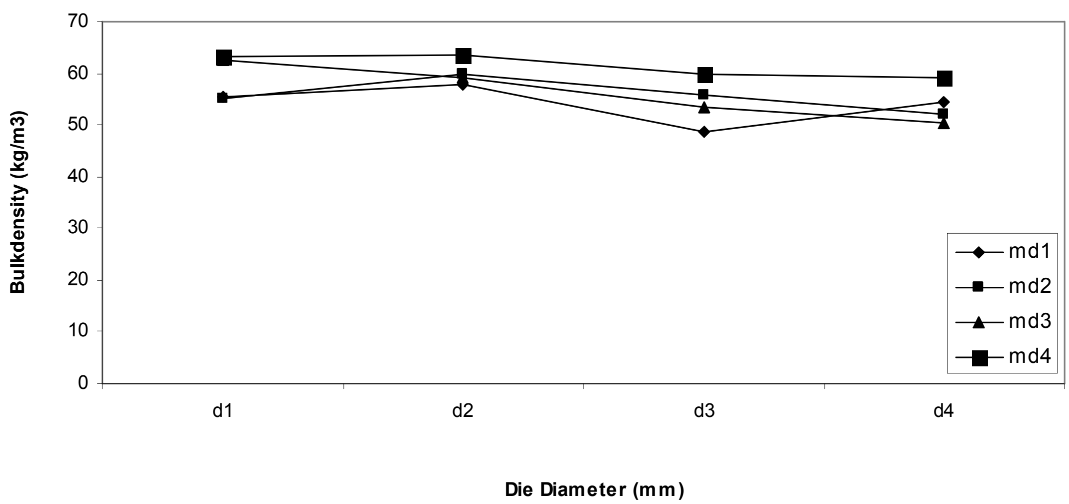

Figure 3: Effect of die diameter on bulk density at different moisture content levels.
Legend: d1=6mm, d2=8mm, d3=10mm, d4=12mm
Md1=48.5%(wb), Md2=50.5%(wb), Md3=52.5%(wb), Md4=54.5%(wb)

Effect of speed on bulk density at different level of die diameter

From Table 1, it is seen that the interaction between the speed of the machine and the die diameter of the extrusion rig has significant effect on the bulk density of the cassava pellets produced at 5% level and this is shown in the Figure 3.

From Figure 3, it can be seen that bulk density had an initial decrease in speed at die diameter level 6mm and 10mm and linearly reduced as speed increased and further increase in speed resulted in decreases in the bulk density. There was an initial increase in the speed for die diameter 8mm and 12mm which further increased as the speed increased and finally led to decrease in bulk density as the speed increased. In summary, despite the initial increase or decrease noticed in bulk density at the four levels of die diameters, all the bulk densities finally decreased with increase in speed levels. This is in agreement with the findings of Heinemans (1991), because release of large quantity of air during compression processes lowers bulk density of pellets which might be responsible for the above observations.

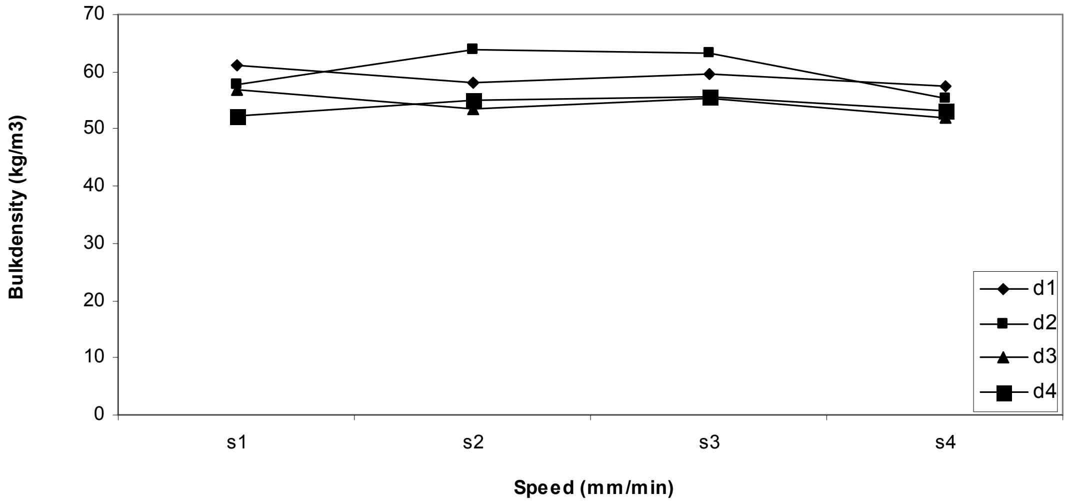

Figure 4.2.3: Effect of speed on Bulk density at different die diameters.

Legend: **d1=6mm, d2=8mm, d3=10mm, d4=12mm**

S1=1.5mm|min, S2=2.5mm|min, S3=3.5mm|min, S4=4.5mm|min.

4. CONCLUSIONS

The following can be drawn from this study:

i) The moisture content of preparation of Cassava dough directly affected the bulk density of the cassava pellets produced. The effect was more pronounced in the case of the highest moisture content level and the lowest moisture content level.

ii).Die diameter of the extrusion rig affected the bulk density of the cassava pellets. The low-erest die diameter produced pellets with higher bulk density.

iii) The higher the speeds of the machine, the lower the bulk density. Therefore, pellets of high bulk density were obtained at lower speed level.

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