The effect of moisture content, particle size and type of feed component on the Physical Properties of Pelleted feed from Forage and Cassava tubers with the peel

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Abstract— **A Pelletizing machine for the production of pelleted feed for grasscutter in captivity was designed and fabricated. It consists of a hopper, a barrel that houses a screw conveyor and eight (8) pipes of 18.0mm diameter evenly located at the outlet. The study was to find out the effect of moisture content, particle size and feed components on the physical properties of the pelleted feed. It was observed that moisture content, particle size and feed component significantly affected the pellet density, bulk density and the pelleted feed durability index at p<0.001. However, the various particle size of the feed component (Elephant grass, Gliricidia leaves and the cassava tuber with the peel) did not produce any significant effect on the density, bulk density and the durability index of the pelleted feed. On the other hand, the types of feed significantly affect both the pellet diameter and length/height at p<0.05 significant levels, but the feed particle size did not have any influence on the pellet diameter and the length. Moisture content did not significantly affect pellet diameter but significantly affected the pellet length at p<0.05. Particle size, type of feed and moisture content significantly at p<0.001 had effect on the pelleted weight. The high durability index of the pellet will enable the pelleted feed to be handled, transported and stored easily as well as been fed to grasscutter without producing any dust and wastage of feed would be minimised since grasscutters are noted as feed wasters. The absence of binders is an added advantage in the use of the machine in pelleted feed production. . It is therefore recommended that grasscutter farmers be encourage to use the machine to pellet their feed that mostly are of forage origins (elephant, grass, Guinea grass, Cassava tubers and peels) with some nitrogenous plant origin like Gliricidia leaves and some commercial ingredients to store and have regular supply of the feed all year round**

Index Terms—**Grassstructure, Hopper,Gliricidia, Cassava.**

I. INTRODUCTION

Grasscutter farmers in Ghana feed their animal on guinea grass, Elephant grass and at times peels of cassava which are in nature poor in nutrition, not palatable and usually low in bulk density. Apart from the mentioned factors bush fires and land clearing for either crop production or for human settlement has compiled grasscutter farmers in Ghana to travel between 3 to 5 kilometres in search of the grasses especially during the lean or dry season that last for a period of between three to five months in the rain forest and the savannah climatic zones of Ghana where the animals thrive respectively. Apart from the biomass been of poor nutritive value they contain a lot of moisture, are irregular in shape and size and difficult to handle, transport, store and utilize in its original form.

In other to make grasscutter farmers to have an all year round feedstuff for their animals, the Department of Agriculture Engineering of the College of Education of the University of Education constructed a pelletizer to pellet a ration made of Elephant grass, Gliricidia leaves and Cassava with the peel as the major feed component with some other commercial ingredients as feed for grasscutters in captivity in Ghana.

According to [1]: [2], and [3], pelleting of animal feed not only increases the bulk density of the individual components of the feed and the transportation, handling and storage but also gives a better flow properties than ground feed, reduces ingredient segregation, less feed wastage, improves animal performance, lower energy expenditure while eating, reduces microbial load and improves palatability and digestibility. Grasscutters unlike other monogastric animals, usually sits on it hind legs and holds the feed substance with the fore limbs to chew, therefore the need to compress its feed into a solid form hard enough for the grasscutter to hold it without shattering or breaking. For this reason there was the need to examine the physical properties of the pelleted feed to ascertain its handling, transport and storage ability.

II. MATERIALS AND METHODS

Four week elephant grass (*Pennisetum purpureum*.) and Gliricidia leaves were harvested from the college cocoa plantation field while the cassava was purchased from a farmer. The selection of the material was based on the fact that they are the most used feedstuff of the grasscutter and are common and available. The elephant grass and cassava tubers were chopped into pieces of sizes between 2-4 cm whiles the gliricidia leaves were left whole. They were separately shade dried at a temperature of 25^{o}C and ground in a hammer mill of sieve size 2.0mm. The ground materials were mixed according to a feed formulated formula together with some industrial ingredients to obtain a crude protein level of 18% as stated by [4].

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Physical properties of the three biomass

Table 1 shows the geometric mean, fineness modulus, geometric standard deviation, bulk density and particle density of the three main components determined according to ANSI/ASAE standard [5].

From the grading test and determination of the particle sizes of the main three components of the feed it could be deduced that the particle were fine (less than 5.0mm) and of different sizes as shown in Table 1 below.

Table 1: Physical properties of the three biomass

Material	Moisture content (%, wb)	No. Passes (2.0mm Sieve)	Particle size(mm)	Geometric mean diameter (mm)	Geometric standard diviation (mm)	Bulk density (kgm^{-3})	Particle density (kgm^{-3})
Elephant grass	2.01	1	3.90	0.76	1.42	208.90	636.861
	2.55	2	3.83	0.75	1.41	263.45	648.081
Gliricidia	.73	1	4.14	0.78	1.40	348.33	718.778
	4.44	2	3.06	0.66	1.45	384.45	781.583
Cavassa with peel	4.64	1	1.54	0.79	1.56	741.43	1124.539
	4.54	2	1.01	0.66	1.55	773.61	1142.381

From the table the particle sizes of the ground raw (Geometric mean diameter, mm) material range from 0.76mm to 0.79mm for one pass through the 2.0mm screen and those of the two passes ranged from 0.66mm to 0.75mm. It was also observed that both particle density and bulk densities of the two passes of the main feed component were higher than the one pass of the component through the 2.0mm hammer mill screen as observed by [6]

The different particle size also encourage high mechanical interlocking and surface tension force to produce stronger and durable pellets in accordance to [7].

Composition of feed rations.

Table 2 gives a descriptive summary of the various levels of inclusion of feedstuffs in the two rations before pelleting.

Table 2 composition of feed rations before pelleting

Ration with Urea (ration 1)				Ration with soya bean meal (ration 2)			
Ingredients	Inclusive level (%)	Crude protein (%)	Calculated crude protein (%)	Ingredients	Inclusive level (%)	Crude protein (%)	Calculated crude protein (%)
Major Ingredient Elephant grass				Major Ingredient Elephant grass			
Gliricidia	45.0	7.40	2.96	Gliricidia	40.00	7.40	2.96
leaves	29.0	19.70	5.52	leaves	28.00	19.7	5.52
Cassava with peel				Cassava with peel			
Urea	22.0	4.4	0.96	Soya bean	10.00	4.4	0.44
	2.8	44	8.05	meal			
Minor Ingredients Dicalcium phosphate				**Minor Ingredients** Dicalcium	21.00	44	9.24
				phosphate	0.25		
Premix	0.28			Premix			
Common salt/table salt	0.35			Common salt/table salt	0.25		
Sodium sulphate	0.44				0.5		
	0.13						
Total	100.00		17.49	Total	100.00		18.16

Pelletizer Operation

The three Phase electrically operated extruder consists of an auger enclosed in a cylindrical barrel. The semi solid mass is pushed through the evenly spaced 18.0mm pipes.

Plate 1. Pelletizer

Pellet density

Ten pellets of each treatment were selected at random and their diameters and lengths were measure using and electronic calliper and their averages determined and used to determine the volume of the pellet. Their masses were also determined using an electronic scale of 0.01g precision. To calculate the volume of each pellet the height of each pellet was measure at three different points and their average was used with their measured diameters. The unit density was then calculated as the ratio of the mass of each sample of the pellet to its volume and the average densities calculated.

Pellet bulk density

The pellet bulk density was determined using a cylindrical container 96.99mm in diameter and 122.59 in height. The samples were poured loosely until the container was over flowing. Excess pellet was removed by passing a straight edge rule across the top. For the tapped density the loosely filled container was tapped on the laboratory table 5 times. Filling and tapping was repeated until the container was overflowing and latter levelled with ruler. The filled container was weight using an electronic scale of 0.01g precision. The material weight of the samples was obtained by subtraction the weight of the empty container.

The bulk, porosity or void space was determine using the equation [8]

$$1 - \frac{\rho b}{\rho d}$$

Where:

$\rho b = bulk\ desity\ of\ pellet$

$\rho d = single\ particle\ density\ of\ pellet$

Durability test of pellet

The pellet durability of the various treatments was determined according to ASAE Standard S269.4.

Twenty pellets of the different moisture levels of each ration was weighed and placed in a tumbling machine Erweka TA 20 and ran at 100 revolution for 4 minutes. The weighs of both crumbled and uncrumbled pellets were taken using a balance with reading up to two decimal places.

The particle collected between the first and second sieve were considered as Broken Pellets (BP)

The percentage of whole pellets was calculated using the formula by [10]:

Unbroken Pellet ((UBP (%)) $= \frac{mass\ of\ pellet\ after\ tumbling}{mass\ of\ pellet\ before\ tumbling} x100$ ....(1)

Broken Pellet ((BP (%)) $= \frac{BP\ (\%)}{Initial\ mass\ of\ sample\ (g)}$ x 100 .... (2)

Then the particle below the 500µm sieve, collected in the pan, were used to estimate the dust percent D(%) as follows:

Dust ((D (%))) $= \frac{D(g)}{Initial\ mass\ of\ sample\ (g}$ .... (3)

Missing dust (%) since it was not collect and weighed it was estimated using equation 4.

Missing dust (%) = $Missing\ dust\ (\%) = 100 - (UBP(\%) + BP\ (\%) + D(\%)$ ... (4)

Dry Pellet Weight (g)

The pelleted feed was allowed two weeks shade drying to acquire uniform dimension and weights before considering their physical properties.

The dried weight of the pelleted feed was determined with a laboratory scale measuring up to 0.01g precision.

Moisture absorption rate

The rate of moisture absorption of the pelleted feed of the two rations was determined by placing them on wet filter papers for a period of 30 minutes.

Statistical Analysis

The multiple regression statistic for the models and Least square means and standard error was determined, [11].

Results

The physical parameters considered were, the pellet durability index, pellet density, pellet bulk density, pellet diameter, pellet length, pellet moisture absorption rate and the pellet weight.

Pellet Durability Index (%)

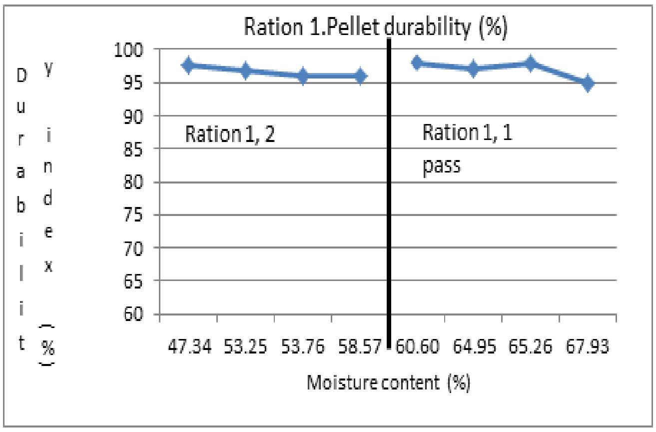

Fig 1a. Effect of moisture content, particle size and type of feed on pellet durability index (%)

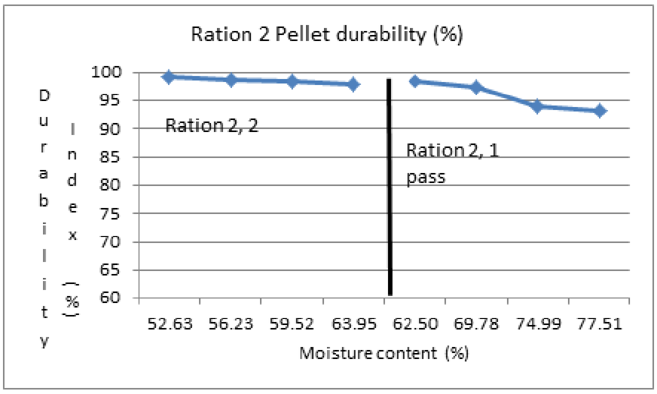

Fig.1b. Effect of moisture content, particle size and type of feed on pellet durability index (%)

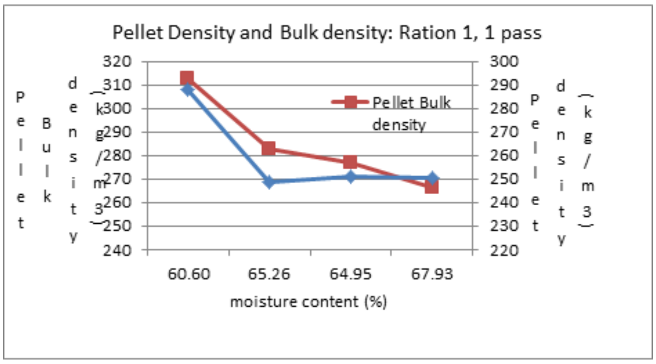

fig 2a. Effect of moisture content, particle size and type of feed on pellet density and pellet bulk density (kg/m^3) Ration 1, (1 pass)

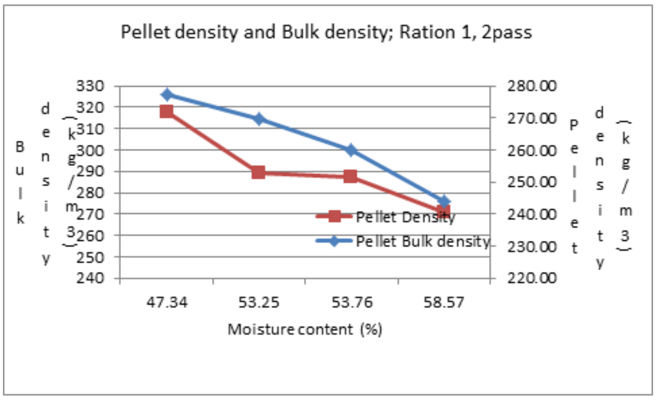

Fig 2b. Effect of moisture content, particle size and type of feed on pellet density and pellet bulk density (kg/m^3) Ration 1, (2 passes)

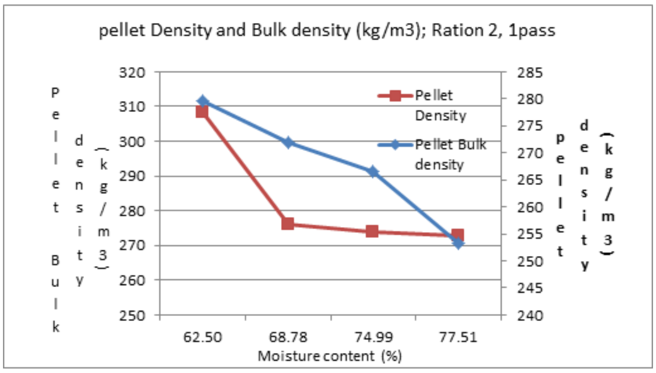

Fig.3a. Effect of moisture content, particle size and type of feed on pellet density and pellet bulk density (kg/m^3) Ration 2, (1 pass)

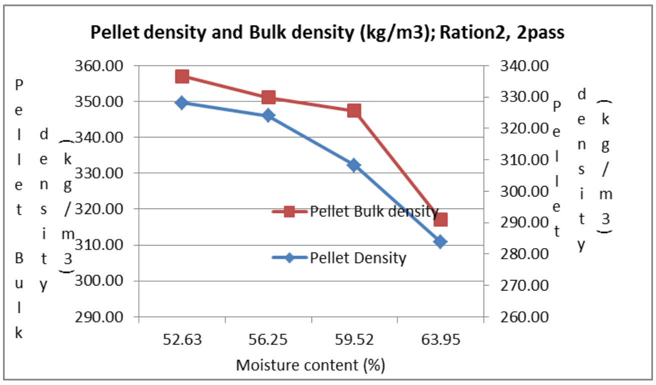

Fig.3 b Effect of moisture content, particle size and type of feed on pellet density and pellet bulk density (kg/m^3) Ration 2, (2 passes)

Pellet diameter and length (mm)

Figures 4 a and 4b show the various diameters and lengths of the pelleted feed of ration 1 at the various moisture contents and particle size of the main feed components.

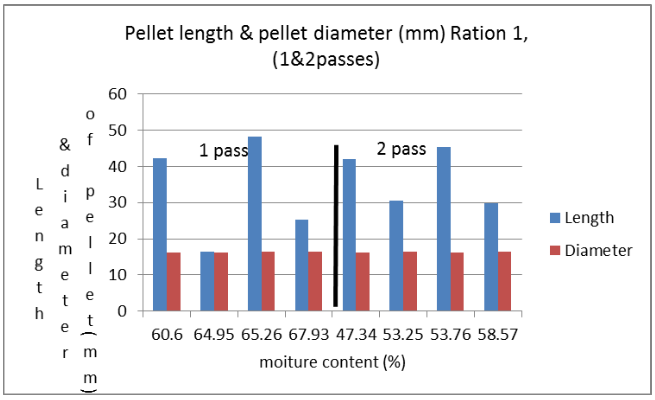

Fig.4a. Pelleted feed diameter and length (ration1, 1 and 2pass)

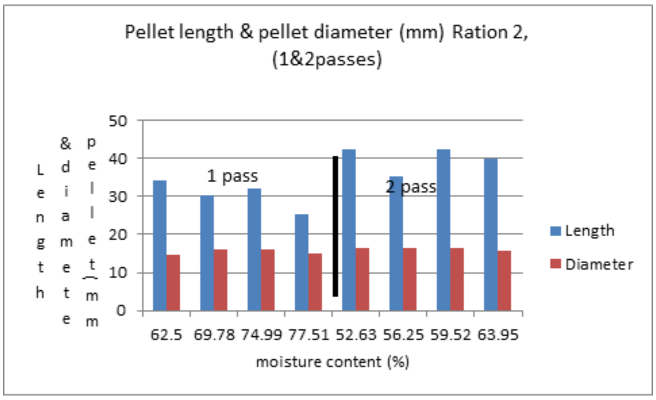

Fig.4b Pelleted feed diameter and length (ration 2, 1 and 2pass)

Dry Pellet Weight (g)

The pelleted feed was allowed two weeks shade drying to acquire uniform dimension and weights before considering their physical properties.

The dried weight of the pelleted feed was determined with a laboratory scale measuring up to 0.01g precision.

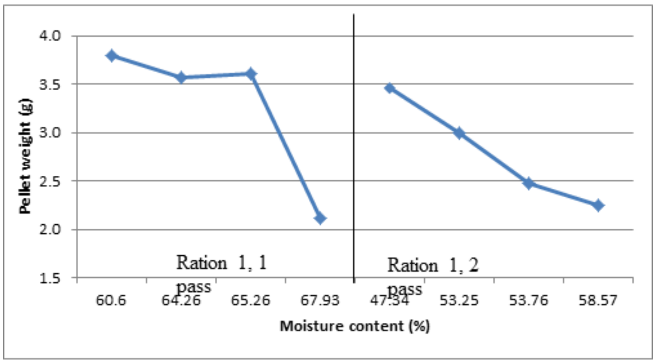

Fig.5a. Pellet dried weight , ration 1 (1 and 2passes)

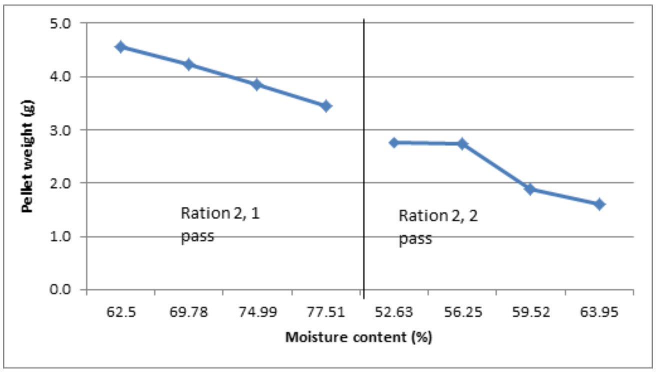

Fig.5b. Pellet dried weight ration 2 (1 and 2 passes)

III. Discussions

Chemical composition

The chemical composition of the three biomass species tested for physical properties is presented in table 4. The high contents of Lignin, Cellulose, Hemi-cellulose and protein influence the pelleting property of the biomass. The combine effect of shear, heat and residence time and water during the pelleting process resulted in the partial denaturation of the protein in the material that may have positively affected the durability of the pellet.

Table 4. Proximate Composition and Energy Values of the three biomass species

Constiuents	Elephant grass (g/100g)	Gliricidia (g/100g)	Cassava and Peel (g/100g)
Crude Protein	7.4	19.7	4.4
Fat	-	-	-
Lignin	36.00	17.00	1.00
Cellulose	16.00	31.00	13.00
Hemi-cellulose	30.00	20.00	10.00
Dry Matter	98.00	97.00	98.50
Crude Fibre	38.89	19.54	2.22
Ash	9.50	8.50	2.00
Moisture content	2.00	3.00	1.5
Nitrogen free Extract			
Acid detergent fibre	39.21	45.26	85.88
Neutral detergent fibre			
Calcium	58.00	47.00	14.00
Phosphorous			
Esther Extract			
Metabolizable Energy	88.00	67.00	24.00
	0.23	026	1.33
	0.23	0.26	0.33
	3.00	4.00	4.00
	1886.35	2613.60	3499.80

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Effect of moisture content, particle size and type of feed on pellet durability.

Pellet durability index is a quality parameter that defines the ability of the pellet to remain intact when handled during storage and transportation. It expresses the physical strength and resistance to be broken up. Figures 1a and 1b, indicate the effect of moisture content, type of feed and particle size on the durability index of the pellets for the two rations (ration1and ration 2) at the various number of passes through the 2.00 mm hammer mill screen.

In all cases, the durability index decreased slightly with increases in moisture content of the feed. It was also realised that, the ration 1 with larger particle size of the main feed component (one pass) recorded higher durability index of 98.06% and 97.94% at the moisture levels of 60.60 and 65.26% respectively. For the two pass feed component the highest durability index of 97.75% was recorded at the lower moisture content of 47.34%.

Pellets produced from ration two (2) recorded higher durability index. The two passed main feed component had their durability index of 99.11 % to 97.80% while that of the one pass ranged between 98.42 to 93.30 %. In all, it was realised that particle size, moisture content and type of feed component had influence on the pelleted feed durability index with the ration that had the soy meal component recording higher values an indication that soy meal improves the binding ability of the individual components due to it high protein and starch content as observed by [12]).

Ration 2 that had the soy meal as one of its feed component had higher durability index ranging from 99.2 to 97.8 for the 2 pass and 98.3 to 93% for the one pass. This is in agreement with the finding of [13] that soy meal helps to improve pellet durability.

In their work, higher percentage levels of protein of the rations combined with the heat created during the pelleting process and the moisture and shear, denatured the protein which helped to induced the binding ability of the protein resulting to higher values of the durability index, hence the higher values of durability index of the two rations, [14]; [15]; [16] and [17].

The higher levels of the crude fibre content of 19.79% and 16.67% of the two rations respectively also contributed to high durability index of the pellets as stated in the findings of [18].

The study showed that, particle size, moisture content and the type of feed had effect on the pellet durability and that the pellet durability decreased with increased moisture content, but was higher with feed rations with wider particle size distribution of the main feed component (rations with one pass of the main component in the hammer mill of 2.0 mm screen size), as reported by [19]). The ANOVA results indicated significance at $p<0.05$ level for all the traits [11].

In general the durability index of the two rations at the various particles sizes and moisture content were high since they all fall above 80% as reported by Colley cited by [20]). According to him Durability is considered high when the calculated value is above 80%, medium when the value is between 70% and 80% and low when the value is below 70%. Low pellet durability is not desirable as it can cause problems such as disturbance within pellet feeding systems, dust emission, and increase risk of fire explosion during pellet handling and storage pellets as reported by [21].

Effect of moisture content of the pellet density and pellet bulk density

Figures 2a to 2d, indicates the effect of moisture content, type of feed and particle size on the bulk density and pellet density of the two rations and their respective particle sizes.

Moisture content of the feed rations significantly affected the pellet density and pellet bulk density. In general as the moisture content of the feed rations increased, pellet density and bulk density decreased as reported by[22].

From the graphs it could be deduced that as the moisture levels increased both the pellet bulk density and pellet densities decreased. The highest bulk densities and densities were recorded with both rations with the two (2) passes of the main component through the 2.0mm sieve screen; Ration1, 2passes had its bulk density ranging from 317.61 to 270.60kg/m^3 and density 277.30 to 243.95kg/m^3 and those of ration 2, 2pass are 356.99 to 317.20 and 328.90 to 283.92 kg/m^3 respectively.

Comparing the densities (pellet density and pellet bulk density), those of ration 2 that had the soy meal as one of the major feed component with high protein level recorded higher values as reported by [19].

This finding is in accordance with that of [3] and [2] that pelleting increases both density and bulk density of biomass materials.

According to [23] and [1] high bulk density would increase storage and transport capacity of the pellet, hence the produce pellet can be stored and transported easily.

Both pellet density and pellet bulk density decreased with increased moisture content. The highest pellet densities and bulk densities were recorded from both rations that had their main feed component of smaller sizes (feed component that passed twice through the two (2) millimetre sieve of the hammer mill). This is in agreement with [24] and [25] in their study on physical properties of biomass, concluded that the bulk density of ground biomass increase with decreased in hammer mill screen size (smaller particle size) and the moisture content.

Ration 1, 2 passes had its bulk density ranging from 317.61 to 270.60 kg/m^3 and the pellet density ranged from 277.30 to 243.95 kg/m^3. The pellet bulk density and density of feed ration 2, 2 pass ranged from 356.99 to 317.2092 kg/m^3 and 328.90 to 283.92 kg/m^3 respectively. In general there were no significant differences in both the bulk density and pellet density at the various moisture contents.

Effect of particle size on pellet density and pellet bulk density

Particle size of the feed component had effect on both the pellet density and pellet bulk density and the ANOVA result showed significant at $p<0.05$, [11], In general the pellet density and pellet bulk density of the feed ration that had smaller particle sizes were higher than those with bigger particle sizes [6]).

particle size has no effect on the pellet density, bulk density and the pellet durability as stated as [20].

Effect of type of feed on pellet density and pellet bulk density.

From the study it was observed that the type of feed did not significantly ($p<0.05$) influence the pellet density and pellet bulk density.

Effect of moisture content on pellet diameter and length.

Initially, the pellet diameter increased with increased moisture but gradually decreased after third level of moisture content (from 61 to 71+ percent). The statistical analysis showed significance at $p<0.05$ for the pellet length and no significance difference with the pellet diameter at the various moisture levels, [11].

In general moisture content have significant ($p<0.05$) effect on most physical properties of the pelleted feed since it is needed for gelatinization of the feed [26].

Effect of type of feed on pellet diameter and pellet length.

From the study it was realised that the type of feed had effect on the pellet diameter and pellet length. When the extruder performance parameters were subjected to statistical analysis, all showed significant at $p<0.05$, [11].

Effect of particle size on pellet diameter and length.

The particle size did not have any significant ($P< 0.05$ level) influence on both pellet diameter and length

Dry Pellet Weight (g)

The dried weight of the various moisture content, type of feed and particle size of the major feed components are presented in Figures 5a and 5b. It was observed that the dried weight decreased with increased moisture content for both feed rations. From the statistical analysis the various parameters (Particle size, feed moisture content and type of feed) had effect on the pellet weight at probability level $p<0.001$.

Averagely, considering the mean weight of the pellets, ration 1 with the one pass, every 50 kg of the pelleted feed would contain approximately One Thousand Five Hundred and Twenty Eight (1,528) pieces whilst that of ration 2 one pass would contain also approximately One Thousand Two Hundred and forty four (1,244) pieces.

Moisture Absorption rate

The different moisture content and type of feed of the rations highly significant, (p<0.001) affected the rate of water absorption of the dried pellets. However, the particle size and time of exposure of the pellet to moisture absorption were not significant.

IV. Conclusion and Recommendations

In general the durability index of the two rations at the various particles sizes and moisture content were high since they all fall above 80%. It was also observed that particle size, type of feed and moisture content significantly (p<0.001) had effect on the pelleted weight. The high durability index of the pellet will enable the pelleted feed to be handled, transported and stored easily as well as been fed to grasscutter without producing any dust, and wastage of feed would be minimised since grasscutters are noted as feed wasters. The absence of the use of commercial binders is an added advantage with the use of the machine in pellet production.

It is therefore recommended that grasscutter farmers could use the machine to pellet their feed that mostly are of forage origins (elephant, grass, Guinea grass, Cassava tubers and peels) with some nitrogenous plant origin like Gliricidia leaves and some commercial ingredients to store and have regular supply of the feed all year round.

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