

Development of a Urea Molasses Multi–Nutrient Block Machine for Sustainable Livestock Production

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Abstract

Locally produced urea molasses multi-nutrient block (UMMB) are prone to contamination, inadequate mixing, inefficient compaction during moulding due to the manual method of production. A machine for the production of UMMB was designed, constructed and evaluated. It comprised of a mixing and a moulding unit. The performance evaluation of the machine was carried out. The parameters investigated were density, compressive strength, bioyield force, moulding efficiency and drying time. The results were subjected to analysis of variance and Duncan Multiple Range Test. The results revealed that moisture content was significant for all the parameters investigated. Hence, further investigation was conducted to ascertain how these parameters vary at moisture content levels of 20, 30, 40, 50 and 60% (db). It was observed that Density decreased with increase in moisture content. On the average, the machine had highest moulding efficiency of 89.89%, compressive strength of 4.38N/mm², bioyield force of 47340N, density of 1058.2 kg/m³ and shortest drying time of 6 hours. Full exploitation of the nutritional, industrial and commercial prospects of UMMB as feed supplements in ruminant nutrition is appropriate.

Keywords

Nutrients, Molasses, Moulding, Mixing and Density.

1. Introduction

Multi-Nutrient feed blocks, which are made for improving the nutritional status of livestock have proven to increase the productivity of livestock. To improve the performance of dairy animals, supply of sufficient nutrients is needed, and cattle feed

block is one of the best and easiest means to achieve this. Feed supplement developed from combination of different agricultural by-products which are converted to useful source of nutrients for essential development of ruminant animals such as goats,

sheep, cattle, buffaloes are commonly referred to as Urea – Molasses Multi-Nutrient Block (UMMB) (Mohammed *et al.*, 2007; Mubi *et al.*, 2013; Mshelizah, 2015; Dzidiya *et al.*, 2015; Gadzama *et al.*, 2016). Essential minerals such as fermentable energy from molasses, non-protein nitrogen usually from urea, calcium from bone meal, sodium and chloride from salt, other essential minerals and vitamins can be sourced from the combination of these supplements (Mohammed *et al.*, 2007; Mubi *et al.*, 2013).

The use of conventional feedstuffs such as maize, soya, groundnut cake to enhance livestock production has become inappropriate. Due to increasing demand from agricultural and industrial users, these feedstuffs are now in short supply. Prices of feeds that could serve as raw materials have skyrocketed and erratic supply of feedstuffs, thereby becoming too expensive for small-scale farmers to incorporate them into ruminant feeds (Asaolu, 2012).

In the Semi-arid environment of Africa, most especially in Nigeria, a major draw-back to ruminant productivity is the low nutritive value of natural forage (Aye and Adegun, 2010). Thus, performance of ruminant animals is inhibited due to poor quality of pastures fed to them (Mshelizah *et al.*, 2015). Likewise, essential minerals and nutrients such as the crude protein content of forages rarely exceeds 6 % for more than six months in a year. Therefore, there is a need for effective supplementation that can provide alternative source of nutrients for milk yields and growth rates (Aduba *et al.*, 2013; Aye, 2016). The unavailability of machine specifically designed for mixing and moulding multi-nutrient blocks at one operation has further necessitated the urgent need to develop indigenous self- sustaining mechanisms such as the UMMB production machine that would reduce the drudgery, labour intensity and time consumption of producing multi-nutrient blocks. Considering these shortcomings and the industrial potentials and economic importance of urea molasses multi-Nutrient block (UMMB), it is therefore the objectives of this research to design, construct and test a UMMB processing machine. It would not only eliminate drudgery associated with manual mixing and moulding UMMB but also ensure availability of needed feed supplements for sustainable livestock production.

2 Materials and Methods

2.1 Description of the Machine

The multi-nutrient block production machine has two active sections namely the

(horizontal) mixer and the block moulding section. The mixer consists of horizontally inclined helical blades attached to a shaft which rotates inside a cylindrical barrel. An elongated discharge chute extends to the mould section where twelve (12) segmented mould is designed to retain and shape the material into squared shape blocks. In the moulding section, two shafts with cams are fixed directly under the pallets in order to help compacts the material introduced into the mould while an adjustable board is

placed on top the mould to provide the material sufficient pressure and good surface finishing. The mixer operation, material compaction and moulding is powered by a 5 hp electric motor while the block removal process is manual. Figure 1 shows an isometric view of the UMMB production machine.

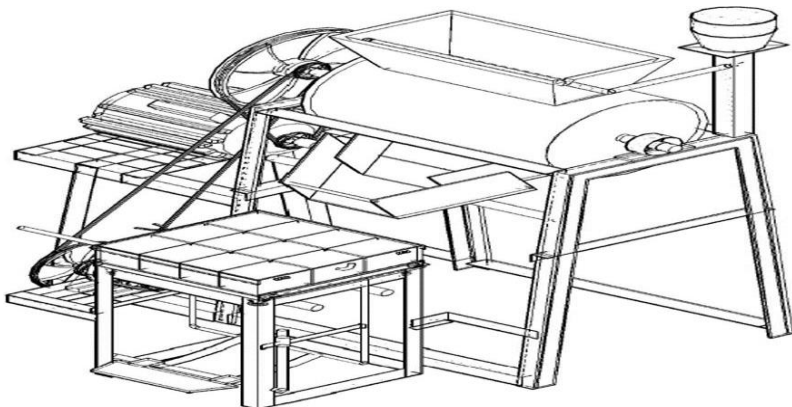


Figure 1: Isometric View of the UMMB Production Machine

2.2 Design Considerations

Having observed the labour involved in the manual mixing and moulding of materials that make up the livestock supplement blocks, the following considerations were taken in the development of the machine:

- i. Simplicity of the horizontal mixer and ease of operation for the users.
- ii. Strength of the locally sourced materials to withstand the force acting on the various components of the machine.
- iii. Component arrangement, placement of controls, power requirement, safety/operational health hazard, hygiene/operational cleanliness, durability, affordability, higher efficiency, and reliability of the machine were also considered.

2.3 Design Calculations

2.3.1 Hopper

The shape of the hopper is trapezoidal with the angle of inclination of 65° which is greater than the range of 33° to 48° angle of repose of the agricultural materials used in this study (Ugwu, 2015). The volume of the material to be fed into the hopper was determined using the equation (1).

$$\text{Volumetric Capacity of hopper} = \frac{\text{Mass of the materials}}{\text{Density of materials}} \quad (1)$$

Since the hopper is trapezoidal in shape, volume was calculated using equation (2).

$$\text{Volume of trapezium} = \frac{1}{2} (A + B) \times H \times L \quad (2)$$

Where A = Upper length of the face of hopper (mm) , B = Lower length of the face of hopper (mm) , L = Side length of hopper (mm), H = Height of hopper (mm)

2.3.2 Mixing Chamber (Cylindrical barrel)

Mixing chamber is the place where the mixing process takes place by the rotation of shaft equipped with helical blades. The discharge gate plate was designed to give room for its sliding forward from underneath the cylinder to allow mixed materials flow out smoothly. To calculate for the volume of cylindrical mixing, equation (3) with was expressed by Khurmi and Gupta, (2005) was used.

$$\text{Volume of Barrel} = \pi \times r^2 \times h \quad (3)$$

Where r = radius of Cylinder (mm), h = Height of Cylinder (mm)

2.3.3 Shaft Design

According to Khurmi and Gupta (2005), shafts are to be designed on the basis of rigidity, strength and stiffness. The shaft required for the mixing operation is attached in between supportive bearing ends. When using a shaft for operation, some actions such as twisting and bending occurs on it. The diameter was calculated using relationship in equation (4).

$$d^3 = \frac{16}{\pi S_s} \sqrt{(k_b M_b)^2 + (K_t M_t)^2} \quad (4)$$

where, d = diameter of the shaft (m) , k_b = combined shock and fatigue factor applied to bending moment, K_t = combined shock and fatigue factor applied to torsional

moment, S_s = Allowable shear stress for the shaft (MPa), M_b = Bending moment (Nm), M_t = Torsional moment (Nm)

2.3.4 Power requirement by the machine

The power requirement of the machine is given by Khurmi and Gupta (2005) as expressed in equation (5).

$$P = \frac{T \times 2\pi N}{60} \quad (5)$$

Where Power required by the shaft (W), T = torque (Nm), N = Speed of the mixer (rpm)

2.4 Sample preparation

The agricultural materials such as bone meal, wheat bran and groundnut cake were sourced from agro vet stores and dry cassava starch from a Garri processing factory in Ilorin metropolis, Kwara State, Nigeria. Limestone (CEM 11/B-L 32.5R) grade was sourced from United Cement Company Limited (UNICEM). Grade C molasses of 79% brix solid and 56% of total sugar was sourced from Dangote Sugar Company while granular urea (N-46% +) was sourced from Indorama Eleme Petro-chemical Company Limited. The Wheat bran, Limestone, and Bone meal were first cleaned. The cleaning involved the removal of dirt and impurities, after which they were pulverized and were oven dried.

2.5 Performance Evaluation of the Machine

The performance evaluation of the machine was investigated using a $2 \times 3 \times 3$ factorial experiment in a completely randomized design at two levels of machine speed (360rpm, 430rpm), three levels of moisture content at 30, 40 and 50% (db) and three levels of binder (1.5kg, 2kg, 2.5kg). The binder used was dry cassava starch. The moisture content (dry basis) of the agricultural materials were determined using the oven drying method as recommended by Ugwu (2015). The materials were divided into samples, each sample were subjected to oven drying using Uniscope Model SM9053 laboratory oven at 115°C for 4 hours to attain a bone-dry weight of the materials has recommended by (Ugwu, 2015) while the amount of water that was added to each batch/samples of the feeds for the UMMB production were determined using the formula expressed by Adejumo and Abayomi (2012) as given in equation (6).

$$Q = W_t \left(\frac{M_f - M_t}{100 - M_f} \right) \quad (6)$$

Where Q = Quantity of water (db), W_i = Initial mass of sample (kg), M_f = Final moisture content of sample (%), M_i = Initial moisture content of sample (%).

Calculated amount of water was added to each of the samples to give the following samples moisture content of 30, 40 and 50% (db) respectively. Each of sample used contained Wheat bran, Molasses, Urea, Limestone, Salt and Bone-meal at quantity 3.0, 1.0, 0.5, 1.0, 0.5 and 1.0kg respectively. The parameters investigated were density, compressive strength, bioyield force, moulding efficiency and drying time. Compressive Strength is the capacity or ability of the UMMB block or structure to withstand loads tending to reduce its size. Bioyield force is the force required to cause a failure in the internal cellular structure of the UMMB block. Moulding efficiency is the ratio of the weight of blocks formed/produced at a single operation to the total weight of mash fed into the moulding machine. Drying time is the time taken to dry the UMMB block to the desired safe storage moisture content. The results of the performance evaluation were subjected to analysis of variance and Duncan Multiple Range Test.

2.6 Effect of Moisture Content on Performance Indices

Another experiment was conducted to investigate the variations in all the tested parameters (moulding efficiency, bioyield force, compressive strength, density and drying time) with moisture content. Five levels of moisture content (20,30,40,50 and 60% db) were used for the study. The machine speed of 360 rpm and binder condition of 2kg were used for this experiment.

3. Results and Discussion

3.1 Mode of Operation of the Machine

The feed ingredients were introduced into the mixer via the hopper (figure 2) located at the upper part of the mixer. With the introduction of materials into the mixing chamber, the rotating action of the centrally positioned horizontal paddles leads to lifts and drops thereby blending the materials continuously for an average set time of 15 minutes. After thorough mixing is achieved, the plate of the discharge chute is opened to allow the mixed materials flow out of the mixer. Complete evacuation of the material was achieved by the continuous rotation of the shaft even after the discharge plate was opened. The mixed mash of material was transferred into the mould through the elongated discharge chute and a wooden scoop was used to evenly spread the mash into all the twelve 130 mm x 90 mm x 90 mm segmented space inside the mould. Pressure application was by the rotation of the shaft with cams at the bottom of the mould to make the materials settle in properly and be compacted. An adjustable board on top of the mould compressed the blocks into shape and gave them good surface finishing. After the adjustable board has been released, pressure was again

applied on the elbows connected to the mould to lift it upward, leaving only the shaped blocks on the wooden pallet to be taken away for drying.

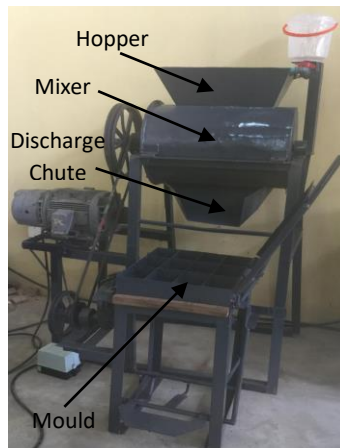


Figure 2. Pictorial View of the Constructed UMMB Machine

3.2.1. Effect of moisture content on Moulding Efficiency

Figure 3 shows the relationship between the moulding efficiency and moisture content. It reveals that the highest moulding efficiency of the UMMB block achieved was 89.89% at moisture content of 40% (db). This conforms with the claim of Kumssa (2017) that for effective moulding efficiency, moisture content should be between 30-60% (db). The moisture content of 40% (db) was sufficient for smooth feed gelatinization thereby ensuring effective moulding to take place. The lowest moulding efficiency recorded was 65.80% at moisture content of 60% (db). It was claimed that moisture inclusion promotes gelatinization of feed components and stretching of expandable components. However, if the moisture content level of the feed material is low, the agglomeration of the material is reduced and unstable blocks are formed (Kumssa, 2017). The range of moulding efficiency achieved in this study is in line with the findings of Ojomo *et al.*, (2010) that increasing moisture in a feed ratio inadvertently increases its gelatinity and stretching of its expandable components, thereby increasing its moulding efficiency.

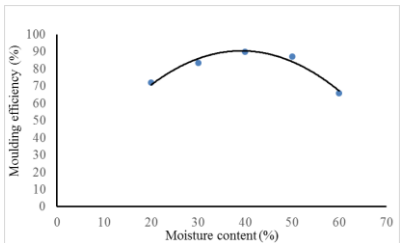


Figure 3. Variations in Moulding efficiency as moisture content changed

3.2.2 Effect of Moisture Content on Bioyield Force

The relationship between bioyield force of the blocks and moisture content is shown in figure 4. It reveals that the highest bioyield force of the UMMB block recorded was 47340 N at moisture content of 40 % (db) while the lowest bioyield force recorded was 13429 N at moisture content of 60 % (db). The results presented in the graph reveals that there is a relationship between moisture content and the bioyield force in the UMMB blocks. The bioyield force peaked at moisture content of 40 % and plummeted down the line at moisture content of 50 and 60% (db). It can be deduced from the graph pattern that to achieve high bioyield force in a UMMB block, the moisture content must be at a considerate level from 20, 30 and 40% (db).

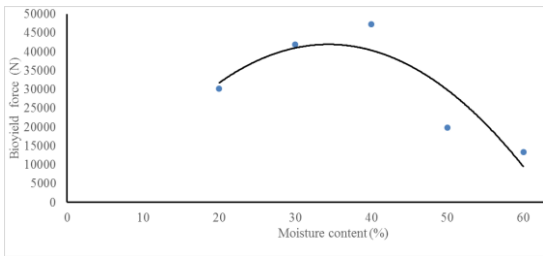


Figure 4. Variations in Bioyield force as moisture content changed

3.2.3 Effect of Moisture Content on Compressive Strength

Figure 5 depicts the relationship between the compressive strength and moisture content of the UMMB blocks. It shows that the highest compressive strength of the block recorded was 4.38 N/mm² at moisture content of 40 % (db) while the lowest compressive strength recorded was 0.8 N/mm² at moisture content of 60% (db). High moisture content could cause increase in slag aggregates percent which in turn leads to porosity and decrease in compression strength as experienced in moisture content of 50 and 60% (db). The values of compressive strength recorded in this study is in conformity with the recommendation of the Nigerian Industrial Standard (NIS 87,

2004), which states that the lowest crushing strength of individual load bearing blocks shall not be less than 2.5 N/mm^2 for machine compaction and 2.0 N/mm^2 for hand compaction, to which ours was higher.

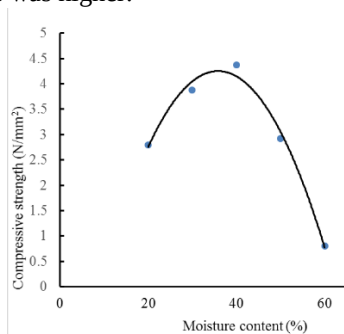


Figure 5. Variations in Compressive strength as moisture content changed

3.2.4 Effect of Moisture Content on Density

The effects of moisture content on density of UMMB block is shown in figure 6. It revealed that the highest density value of the block recorded was 1058.20 kg/m^3 at moisture content of 20 % (db) while the lowest block density was 661.38 kg/m^3 at moisture content of 60% (db). The graph revealed that as moisture content increased, the density decreased. At 20% (db), the density recorded was highest, which inadvertently suggest that to achieve a high densified block, moderate quantity of moisture content is required. The graph also revealed that higher moisture content does not favour high density values due to porosity effects which weakens the inter-particulate bonding present in the materials, thereby making the materials become too soft and weak for moulding which leads to low density. Several researchers have reported that densification would result in densities in the range of 450 to 700 kg/m^3 depending upon feedstock and densification conditions (Kaliyan and Morey, 2009; Kaliyan *et al.*, 2009). The highest density value (1058.20 kg/m^3) derived at 20% (db) moisture content in this study, was much higher than $550 - 600 \text{ kg/m}^3$ obtained by Samantha *et al.* (2003) in the production of Barbari goats complete diets at the same moisture level. Likewise, the density value of 992 kg/m^3 derived at 30% (db) was also higher than $450 - 500 \text{ kg/m}^3$ obtained by Singh *et al.* (2008) in the production of sheep and goat fed roughages of completed feed block at the same

moisture content. The results in this study agrees with the submission of Singh *et al.*, (2016) that Urea Molasses Multi – Nutrient should be solidified and high in density.

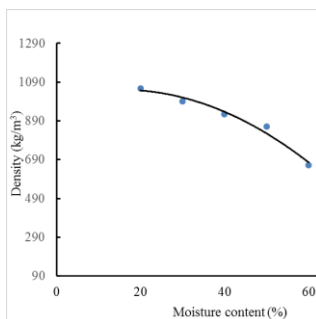


Figure 6. Variations in Density as moisture content changed

3.2.5 Effect of Moisture Content on Drying Time

Drying time as shown in figure 7 increased as moisture content increased. It could be observed from the graph that at moisture content of 20% (db), drying time took 6 hours, while it took 22 hours of continuous drying at moisture content of 60% (db). This agrees with the results obtained by Ndukwu, (2009) that drying time is a strong function of temperature, air velocity and time. While drying time readings were being taking during performance tests, using the (UNISCOPE) oven drying method, moisture loss was observed to be highest at the first two hours of continuous drying for all temperatures which decrease with time. As the drying progressed, more energy was required to break the molecular bond of the moisture and since constant energy was supplied, it took longer to break therefore, the drying rate decreased.

This results obtained here agrees with the position of (Musa *et al.*, 2010; Ibezim *et al.*, 2008) that the quantity of moisture used has a considerable influence on the drying characteristics of the compressed blocks. Since moisture itself serves as a binder, the findings here also tallies with the claim of Akiyama *et al.*, (1989) and Somsveb (1993) that increasing binder in feed ratio also helps in strong sticking together of the feed (block) which is a function of the adhesive properties of the Urea Molasses Multi-Nutrient Block. The dried Urea Molasses Multi-Nutrient Block produced are shown in Figure 8.

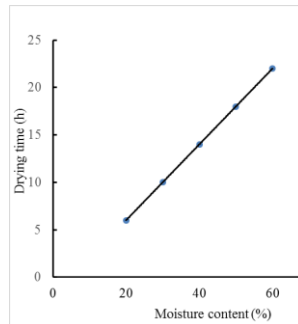


Figure 7. Variations in Drying time as moisture content changed



Figure 8: Dried Samples of urea molasses multi-nutrient block
Produced on Pallets

4. Conclusions

The UMMB mixing and moulding machine was designed, constructed and tested. The performance evaluation of the machine was on the basis of density, compressive strength, bioyield force, moulding efficiency and drying time. Moisture content was significant for all the parameters investigated. Drying time increased as moisture content increased but density decreased as moisture content increased. The machine had highest moulding efficiency of 89.89%, compressive strength of 4.38N/mm^2 , bioyield force of 47340N, density of 1058.2 kg/m^3 and shortest drying time of 6 hours.

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