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STUDIES ON THE PHYSICAL CHARACTERISTICS OF SOME FEED INGREDIENTS IN NIGERIA 2: ENERGY SOURCES AND NOVEL FEEDSTUFFS

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ORIGINAL ARTICLE

ABSTRACT: *Physical characteristics such as particle size (PS), bulk density (BD), water holding capacity (WHC) and specific gravity (SG) of six (6) feed raw materials energy sources (maize (MZ), sorghum (SGH) and cassava flour (CF)) and novel feedstuffs (leaf meal from Microdesmis puberula (LEM), poultry dung (PD) and rumen digesta (RD)) were also studied. The effects of different PS (unmodified, ≥1.00 mm and <1.00 mm) on BD, WHC and SG of the experimental materials were studied using a Randomized Completely Block Design (RCBD). Particle size effect was significant for BD, WHC and SG characteristics of the feed ingredients studied. SGH and PD consistently recorded higher BD values across PS than other feed ingredients in their individual groups. In the energy group, SGH, CF and MZ had the highest WHC at unmodified, ≥1.00 mm and <1.00 mm PS respectively. The WHC value of the LEM (5.50 g water/g feed) used in this study was twice higher than values for PD and RD at the <1.00 mm PS suggesting the possibility of a high content of soluble non-starch polysaccharides. Energy group (MZ, SGH, and CF) had reduced SG values as the PS was modified from ≥1.00 mm to <1.00 mm PS. The physical characteristics of feed ingredients studied cannot be concluded to be optimal since the standard values for the country do not exist.*

Keywords: *Maize; sorghum; poultry dung; rumen digesta; particle size; water holding capacity; bulk density; specific gravity.*

INTRODUCTION

Feed includes any substance, whether processed, semi processed or raw, which is used for animal consumption. It includes, therefore forage crops, manufactured feed and such things as animal and human waste (FAO, 1997). This same report also stated that almost all the feed and feed raw materials ranging from cereals, vegetable proteins, plants with natural toxins (cassava, legumes, etc), fruits and other crop by-products, household and catering waste, animal by-products are at risk of having their quality and safety compromised.

Feeding animals in any intensive livestock enterprise takes up to 70% of the total input of the enterprise (Amir et al., 2001). This fact makes research and discussion of feeds and feeding the vital issues with the prime goal of cutting down huge costs expended on feeding the animals, without compromising the quality of feed or the potential of the animal to efficiently produce at its peak. The goal has led to several studies on novel feedstuffs, some of which have benefited livestock production, while some still require further studies (Udedibie, 2003; Esonu et al., 2002; Esonu et al., 2003; Adeola and Olukosi, 2008; Dale, 2008; Iyaye, 2008).

However, very little has been done about the quality of these novel feedstuffs, with the focus being mostly on nutrients they could supply. The influence of physical characteristics of feeds and feedstuffs on the production of livestock in the tropics has particularly received limited attention over the years probably because this is not considered a major factor of influence on livestock productivity (Omede, 2008). Therefore, this neglect of physical characteristics of feed or feedstuff might be one of the hidden reasons why animals eat so much and yet have little yield to the farmer or why some intensively kept animals eat below their productive requirement in the tropics.

Physical characteristics of feed ingredients used in formulating poultry feeds in Nigeria are not known because these physical characteristics are not popular research issues, contrary to those identified by Omede (2008), in feed quality evaluation. These physical characteristics are not included in the quality scheme for

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nutritional requirements for poultry by the Standards Organization of Nigeria (Standards Organisation of Nigeria, 2003). Their effects are therefore not known, especially in the use of numerous alternative feedstuffs currently promoted by nutritionists in the country. Lack of such information has led to difficulty in predicting the actual optimal inclusion levels of these alternative feedstuffs in poultry rations. Furthermore, the probable effects of the endogenous physical characteristics of alternative feedstuffs may have been erroneously attributed to the effects of anti-nutritional substances in the feed ingredients. Again, the effects of alterations and processing on these physical characteristics, which are known to influence them have not received research attention especially in locally promoted alternative feedstuffs (Baker and Herrman, 2002; Esonu et al., 2002; Esonu et al., 2003; Udedibie, 2003; Esonu et al., 2004; Amerah et al., 2007).

Similarly, information on the important physical characteristics of feed ingredients utilized in Nigeria livestock industry needed for the development of legal schemes and feed quality regulation framework for the country are lacking. Thus, the impact of poor quality feed ingredients on the poultry industry and information needed for proper intervention and amelioration of the problem are lacking. Therefore, the regulatory agencies are ill equipped to properly enforce standards.

The objective of this study therefore was to determine the physical characteristics (particle size, bulk density, water holding capacity and specific gravity) of some energy sources and novel feedstuffs utilized in Nigeria and the effect of different particle sizes on the other physical characteristics.

MATERIALS AND METHODS

Experimental site

This research was conducted at the Animal Science Laboratory of the Department of Animal Science and Technology, Federal University of Technology, Owerri, Imo State, Nigeria between September, 2008 and February, 2009.

Experimental materials

Maize (MZ), sorghum (SGM), and cassava flour (CF) grouped as energy sources and leaf meal (*Microdesmis puberula*) (LEM), rumen digesta (RD) and poultry dung (PD), grouped as novel feedstuffs used in feed formulation Owerri were subjected to various physical characteristics measurements to determine their Particle sizes (PS), Bulk density (BD), Water-holding capacity (WHC) and Specific gravity (SG).

Sample selection and collection

A formal diagnostic survey of feedstuffs used in feed formulation in Owerri was conducted and this led to the selection of the four most utilized protein sources and industrial by-products poultry feed ingredients in Owerri. At the point of collection, about one (5) kilogram of each type of feed ingredient was collected. This was put in cellophane bags, which were appropriately labeled accordingly and later grouped according to feed types as shown in Table 1. Only feedstuffs that had not stayed beyond a week in the store were sampled and collected. Rumen digesta and poultry dung were collected fresh from the abattoir and poultry houses respectively before further processing.

Table 1 - Feedstuffs groups and the various feed ingredients used in the experiment

Feed ingredient groups	Feed ingredients		
Energy sources	Maize	Sorghum	Cassava flour
Novel feedstuffs	Leaf Meal	Rumen digesta	Poultry dung

Particle size (PS) measurement

Three particle sizes were determined using sieve analysis (ASAE, 1983; Jillavenkatesa et al., 2001). The first was an unmodified sample of the experimental materials. The sample were then subjected to the laboratory analyses obtain the desired different particle sizes. One kg weight of each experimental sample was measured out, passed through a 1.00 mm mesh sieve to determine coarse and fine particles. Pelleted feeds were crumbled it with a laboratory mortar for 5 minutes before sieving.

The samples under the sieve (<1.00 mm particles) were classified as fine, while the particles left in the sieve (≥1.00 mm particles) were classified as course, while the original sample was classified as unmodified. These modified samples sizes were further subjected to bulk density, water-holding capacity and specific gravity measurements in four replications as done to the unmodified samples in order to study the effects of particle size on these parameters.

Bulk density (BD) measurement

The method described by Makinde and Sonaiya (2007), was adopted. To obtain the BD of the experimental materials, a Pyrex glass funnel of known volume (165 cm^3, 75 mm internal diameter) was first weighed with a weighing balance (Silvano, Model BS-2508). The test sample material was then poured into the funnel and leveled

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off to the brim without pressing. The funnel and its content were weighed again and the initial weight of funnel subtracted from the final weight to obtain the weight of the test material.

The weight of the test material was then divided by the known volume of the funnel. For example, the bulk density of a dry feed sample weighing 50 grams in a 165-cm^3 funnel will be: 50 grams/ 165 cm^3 = 0.3030 g/cm^3 (Makinde and Sonaiya, 2007). This step was replicated four times for each experimental material, both as unmodified and modified samples (<1.00 mm and ≥1.00 mm particles).

Water holding capacity (WHC) measurement

The filtration method described by Makinde and Sonaiya (2007), was adopted with slight modification. A Pyrex glass funnel of known volume (165 cm^3, 75mm internal diameter) lined inside with filter paper (Whatman No. 1, 11 mm diameter) was weighed (Silvano, Model BS-2508). A sample of the test sample material was poured into the funnel and leveled off to the brim without pressing. Another filter paper was placed on the top of the test material. The funnel and its content were weighed again and the difference between both weights determined to obtain the dry weight of the test sample material. The funnel and its content were set-up below a burette filled with water.

Water dropping from the burette (about 70 drops per minute) was allowed through this known volume of test sample material in the Pyrex funnel and at the first drop of water from the funnel, the burette was stopped and the wet sample weighed. The volume of water absorbed by the test sample material was read-off from the burette. The initial weight of the funnel and its content was subtracted from the final weight (weight of the wet set-up) to obtain the weight of water absorbed by the test sample material. The weight of water held by the sample material to the weight of the dry feed was given as the water holding capacity of the sample in g water/g dry feed. It is assumed in all cases that the initial percentage water content of the dry feed raw materials tested ranged between 12 and 14% (Omede, 2004). This step was repeated four times for each sample/experimental material, both as unmodified and modified samples (<1.00 and ≥1.00 mm particles).

Specific gravity (SG) measurement

Specific gravity of a substance is a comparison of the density of that substance relative to a standard value (density of water). The procedure used in determining BD will be repeated to determine BD of test sample material of one kg. This BD value will be used to determine SG of the test sample material. SG is determined as a ratio of the bulk density of known mass of the experimental sample to the density of water for both the unmodified and modified samples (<1.00 and ≥1.00 mm particles). For example, if the BD of a given test sample material is given as 0.5 g/cm^3, the SG of that given test sample material will be given thus:
BD of test sample material/the Density of water (1.0 g/cm^3)
= 0.5 g/cm^3 /1.0 g/cm^3
= 0.5

Statistical analyses of data

Data generated on PS, BD, WHC and SG of feed raw materials were subjected to analysis of variance (ANOVA) and where significant differences were established among means, they were separated using SAS statistical software (SAS, 1999).

RESULT AND DISCUSSION

The physical characteristics of energy sources and novel feedstuffs frequently used as feed ingredients in Nigeria in monogastric animal feed manufacturing/compounding were studied. The overall bulk density (BD), water holding capacity (WHC) and specific gravity (SG) of these ingredients ranges from 0.02-0.41 (g/cm^3), 0.35-0.89 (g water/g feed) and 0.02-0.41 respectively. From the results obtained in this study, different feed raw materials even within the same group had different physical characteristics. Implication of this is that level of inclusion of each feed raw material in final feed formulation will be influenced by these variations in physical characteristics and would influence the ceiling of inclusion.

The only known study closely related to this area in Nigeria was done by Makinde and Sonaiya (2007), who studied water, blood and rumen fluid absorbencies of some fibrous feedstuffs. Specifically, the physical characteristics of all groups of feed raw materials used in Nigeria are not known. There is currently no standard in this aspect as a vital issue for feed manufacturers (Standards Organisation of Nigeria, 2003). It is known that the performance of any compounded feed is a summary of the individual contributions from the different raw materials used in producing such feed. This makes it a matter of urgency to consider the quality of feed raw materials not only in terms of their nutritional potential but also of their physical characteristics and quality in the formulation of commercial feeds. De Lange (2000), having studied an overview of the determinants of the nutritional values of feed ingredients made mention of the highlighted the effect of certain physical characteristics of feed ingredients.

In the energy sources group (Table 2), Sorghum, though had the highest BD, was similar ($P>0.05$) to CF in BD and SG, while MZ had the lowest BD and SG. MZ and SGM had similar ($P>0.05$) WHC values which were significantly higher ($P<0.05$) than that of CF. SGM having the highest WHC suggests that it may likely contain higher

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value/quantity of water soluble NSPs than others. MZ having a lower BD than SGM is as expected since it has a higher fibre content than SGM (Aduku, 1993).

Table 2 - The BD, WHC and SG of energy sources used in this experiment

Feed raw materials	BD (g/m^3)	WHC (g water/g feed)	SG
MZ	0.33^b	0.78^a	0.33^b
SGM	0.41^a	0.89^a	0.41^a
CF	0.34^a	0.62^b	0.34^a
SEM	0.0251	0.0783	0.0251

MZ = maize, SGM = sorghum; CF = cassava flour (sun dried); BD = bulk density; WHC = water holding capacity; SG = specific gravity; ^{ab} means within a column with different superscript are significantly (P<0.05) different.

In the Novel feedstuffs (Table 3), LEM was significantly (P<0.05) lower than RD and PD in BD and SG. In their WHC, RD recorded the highest value but was similar (P>0.05) to LEM. LEM seems to have more fibrous matter than the rest of the feed, while PD would have had a very low fibrous content for it to record the highest BD. The poultry dung is a waste product from digestion in poultry and the digestion process must have broken down the fiber in the original feed. RD recorded the highest WHC value. The microbes in the rumen of the animal (cattle) from which RD was obtained may have helped to break down RD the more, having exposed its surfaces for more water absorption. These novel feedstuffs need further study in the area of their physical quality and characteristics since as at now interest is more in researches focusing on their nutritive and replacement values for conventional raw materials of feeds.

Table 3 - The BD, WHC and SG of some Novel feedstuffs used in this experiment

Feed raw materials	BD (g/m^3)	WHC (g water/g feed)	SG
LEM	0.02^b	0.60^{ab}	0.02^b
RD	0.09^a	0.67^a	0.09^a
PD	0.30^a	0.35^b	0.30^a
SEM	0.0841	0.0982	0.0841

LEM = leaf meal (*Microdesmis puberula*); RD = rumen digesta; PD = poultry dung; BD = bulk density; WHC = water holding capacity; SG = specific gravity; ^{ab} means within a column with different superscript are significantly (P<0.05) different

Particle size (PS) effects on the physical characteristics (BD, WHC and SG) of some cereals and tubers used as feed raw materials.

In Table 4, it was observed that all members of the cereals and tuber group of feed raw materials had significantly different (P<0.05) and higher BD between their unmodified PS and in modified particle sizes with the exception of SGM at the ≥1.00mm PS where there was similar (P>0.05) value with other particle sizes. The BD of these feed raw materials were relatively moderate and uniform when compared with other feed raw materials groups indicating uniform particle size in the original unmodified sample.

Table 4 - Particle size effects on BD of some cereals and tubers used as feed raw materials

Feed raw materials	BD (g/m^3) at different particle sizes			
	Unmodified PS	≥1.00mm PS	>1.00mm PS	SEM
MZ	0.33^a	0.30^b	0.30^b	0.0100
SGM	0.41^a	0.36^{ab}	0.32^b	0.0260
CF	0.34^a	0.30^b	0.30^b	0.0133

MZ = maize; SGM = sorghum; CF = cassava flour (sun dried); BD = bulk density; ^{ab} means within a column with different superscript are significantly (P<0.05) different.

According to a document by America's Pork Check off Program (2008), low bulk density of feed ingredients will decrease the bulk density of the final diet and that to increase bulk density; the ingredients are often sold in a pelleted form.

In their WHC (Table 5), while MZ and SGM had significant differences (P<0.05) between ≥ 1.00 mm PS and < 1.00mm PS, their values at the modified particle sizes were not significantly different from the WHC values at their unmodified PS. Hence, differences in WHC occurred with change in particle size. However, in CF, significant difference (P<0.05) was only observed in the WHC values between the unmodified PS and the ≥1.00 mm PS, while there was no significant difference (P>0.05) in its WHC when the particle size was reduced. Unexpectedly, the WHC value of MZ at ≥ 1.00 mm particle size was very low compared to what was obtained by Sundu et al. (2005), who reported 1.94 (g water/g feed) for corn, though the value for MZ was closer to this when the particle size reduced to <1.00 mm. Probably, there was more of the <1.00 mm PS in the unmodified PS of maize used in this study. Hence, using any of these in formulating commercial feed for any animal will be dependent on the knowledge of their individual particle size and the desired WHC or any other physical characteristics of interest to the feed manufacturer.

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Table 5 - Particle size effects on WHC of some cereals and tubers used as feed raw materials				
Feed raw materials	WHC (g water/g feed) at different particle sizes			
	Unmodified PS	≥1.00mm PS	>1.00mm PS	SEM
MZ	0.78^{ab}	0.10^{b}	1.20^{a}	0.3204
SGM	0.89^{ab}	0.32^{b}	0.98^{a}	0.2066
CF	0.62^{a}	0.48^{b}	0.50^{ab}	0.0437

MZ = maize; SGM = sorghum; CF = cassava flour (sun dried); BD = bulk density; ^{ab} means within a column with different superscript are significantly (P<0.05) different.

In Table 6, it was observed that all members of the cereals and tuber group of feed raw materials had significantly different (P<0.05) higher SG between their unmodified PS and modified particle sizes with the exception of SGM at the ≥1.00 mm PS where there was similar (P>0.05) values with other particle sizes.

Table 6 - Particle size effects on SG of some cereals and tubers used as feed raw materials				
Feed raw materials	SG at different particle sizes			
	Unmodified PS	≥1.00mm PS	>1.00mm PS	SEM
MZ	0.33^{a}	0.30^{b}	0.30^{b}	0.0100
SGM	0.41^{a}	0.36^{ab}	0.32^{b}	0.0260
CF	0.34^{a}	0.30^{b}	0.30^{b}	0.0133

MZ = maize; SGM = sorghum; CF = cassava flour (sun dried); BD = bulk density; ^{ab} means within a column with different superscript are significantly (P 0.05) different.

Particle size (PS) effects on the physical characteristics (BD, WHC and SG) of some novel feedstuffs.

All Novel feedstuffs had significantly higher (P<0.05) BD values in <1.00 mm PS than in ≥ 1.00 mm PS (Table 7). Furthermore, significant difference (P<0.05) in BD was noticed between unmodified PS and ≥1.00 mm PS in RD, while the BD value of PD at the unmodified PS was similar (P>0.05) to the values obtained in the two modified particle sizes. In the case of the novel feedstuffs, increase in BD was recorded with a reduction in particle size in almost all group members. LEM and RD had relatively low BD (0.02-0.09 g/cm^{3}) when compared with PD (0.26-0.36 g/cm^{3}). For efficient application in feed formulation, LEM and RD may need to be utilized only in pelleted rations in order to override their natural low BD characteristics.

Table 7 - Particle size effects on BD of some Novel feedstuffs				
Feed raw materials	BD (g/m^{3}) at different particle sizes			
	Unmodified PS	≥1.00mm PS	>1.00mm PS	SEM
LEM	0.02^{b}	0.02^{b}	0.03^{a}	0.0033
RD	0.09^{a}	0.06^{b}	0.09^{a}	0.0100
PD	0.30^{ab}	0.26^{b}	0.36^{a}	0.0290

LEM = leaf meal (*Microdesmis puberula*); RD = rumen digesta; PD = poultry dung; BD = bulk density; ^{ab} means within a column with different superscript are significantly (P<0.05) different.

In their WHC, as shown in Table 8, all novel feedstuffs recorded the highest and significantly different (P<0.05) WHC at their <1.00 mm PS, when compared to the values obtained in their unmodified PS and ≥ 1.00 mm PS except for LEM, where the WHC value at the ≥1.00mm PS was similar (P>0.05) to the values in the other two particle sizes. LEM at the <1.00 mm PS was more than twice higher in WHC than the rest of the members of the group. Grinding LEM and RD must have provided more surface area on them. This may have also destroyed the cell walls and the bond that can withstand water. Also, this is an indication of the degree of soluble NSP that may be contained in them. It would seem that the inclusion of fine particles of LEM in the finished feed may influence feed intake to a large extent since the material is capable of swelling 8 times its normal size in the presence of water, thus, affecting satiety.

Table 8 - Particle size effects on WHC of some Novel feedstuffs				
Feed raw materials	WHC (g water/g feed) at different particle sizes			
	Unmodified PS	≥1.00mm PS	>1.00mm PS	SEM
LEM	0.61^{b}	0.75^{ab}	5.50^{a}	1.6071
RD	0.67^{b}	1.13^{b}	2.72^{a}	0.4755
PD	0.35^{b}	0.24^{b}	0.67^{a}	0.0290

LEM = leaf meal (*Microdesmis puberula*); RD = rumen digesta; PD = poultry dung; BD = bulk density; ^{ab} means within a column with different superscript are significantly (P<0.05) different.

All novel feedstuffs had significantly higher (P<0.05) SG values in < 1.00 mm PS than in ≥ 1.00 mm PS (Table 9). Furthermore, significant difference (P<0.05) in SG was noticed between unmodified PS and ≥ 1.00 mm PS in RD, while the SG value of PD at the unmodified PS was similar (P>0.05) to the values obtained in two modified particle sizes. In the case of the novel feedstuffs, increase in SG was recorded with a reduction in particle size in almost all group members.

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Table 9 - Particle size effects on SG of some Novel feedstuffs

Feed raw materials	SG at different particle sizes			
	Unmodified PS	≥1.00mm PS	>1.00mm PS	SEM
LEM	0.02[b]	0.02[b]	0.03[a]	0.0033
RD	0.09[a]	0.06[b]	0.09[a]	0.0100
PD	0.30[ab]	0.26 [b]	0.36[a]	0.0290

LEM = leaf meal (*Microdesmis puberula*); RD = rumen digesta; PD = poultry dung; BD = bulk density; [ab] means within a column with different superscript are significantly ($P<0.05$) different.

Because SG is a factor correlated directly to BD, in like manner, SGM (energy source), and PD (novel feedstuff) consistently recorded the highest SG values as was observed in their BD when compared to other feed raw materials in their individual groups almost at all particle sizes. Knowing the individual SG values of feed raw materials is very important because the SG of the final feed produced from varying feedstuffs will be determined by the SG values of its individual feed ingredients composition. The floatability of commercial feeds will be affected by the SG of the ingredients they are made of. However, the SG values obtained in this study were very low and may likely float within the GIT of monogastric animals if fed as single diet as none of the feed raw materials had SG value up to 1.2, which was the minimum feed particle SG suggested by Bhatti and Firkins, (1995) and Kaske et al. (1992).

CONCLUSION

There are practically no standard evaluation methods for physical characteristics (particle size, bulk density, water holding capacity and specific gravity) of feed ingredients used in formulating poultry feeds by feed manufacturers in Nigeria. The Standards Organization of Nigeria does not have records of what should be optimal the quality standards for physical characteristics of feed manufactured in Nigeria.

As a result, the physical characteristics of feed ingredients in Nigeria are not known. The relationships existing between these physical characteristics and their influences on formulated feed as well as on poultry performance are not known. From this study, it can be established that there is a negative correlation between bulk density and water holding capacity of feed ingredients. An increase in bulk density in this experiment results to decrease in water holding capacity of feed ingredients studied.

Therefore, there is the need for provision of national feed regulatory program with measures based as much as possible in international standards set by appropriate organization for the animal production sector. There should be an integration of regulatory frame works across the stake holders and sectors (Standards Organization of Nigeria, National Food and Drugs Administration and Control, Veterinary Council of Nigeria and Nigeria Institute of Animal Science), e.g. having agricultural health laws and regulations and enforcement rather than having varied laws and organizations controlling animal and plant health issues in the country.

Feed quality assurance program in Nigeria should encompass the goals of quality assurance programme, ingredient quality covering all aspects listed by Okoli et al. (2009); Omede (2008), and Okoli et al. (2007a, b), production and processing methods of feeds, finished feed quality. The purchasing agents and end-users of manufactured feed ingredients must request for quality assessment reports from their manufactured or feed raw materials suppliers.

Further studies need to be done to validate or explain further the results obtained in this study and the claims made. There is also the need to conduct a feeding trial using feeds compounded with the feed ingredients studied herein with animals, considering their physical characteristics as obtained herein to ascertain the effects of these physical characteristics on animal performances and productivity level.

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