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STUDIES ON THE PHYSICAL CHARACTERISTICS OF SOME FEED INGREDIENTS IN NIGERIA 1: PROTEIN SOURCES AND INDUSTRIAL BY-PRODUCTS

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ABSTRACT: *Physical characteristics such as particle size (PS), bulk density (BD), water holding capacity (WHC) and specific gravity (SG) of eight feed raw materials grouped into protein sources (groundnut cake (GNC), soybean meal (SBM), foreign fishmeal (FFM) and local fishmeal (LFM)) and industrial by-products (wheat offal (WO), brewers' dried grains (BDG), palm kernel cake (PKC) and rice husk (RH)) were 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. SBM and PKC consistently recorded higher BD values across PS than other feed raw materials in their individual groups. Among the protein sources, decreasing the particle size, (≥1.00 mm and <1.00 mm) increased the BD values of GNC and SBM and then FFM and LFM respectively. SBM proved to hold more water than the other protein feedstuffs across all PS. At <1.00 mm PS, RH had the lowest capacity to absorb water. Again, GNC and SBM SG values increased at ≥1.00 mm PS and subsequently decreased at <1.00 mm PS. FFM and LFM also had increased SG value up to the <1.00 mm PS. Industrial by-products (WO, BDG, PKC and RH) did not follow similar pattern in their PS-SG effects. Type of machines used and processing methods applied on these industrial by-products may be an explanation to that observation.*

Key words: *groundnut cake; soybean meal; rice husk; palm kernel cake; particle size; water holding capacity; bulk density; Specific gravity.*

ORIGINAL ARTICLE

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; Okoli 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.

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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 nutritional requirements for poultry by the Standards Organization of Nigeria (Standards Organization 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 protein sources and industrial by-products 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

Groundnut cake (GNC), soybean meal (SBM), local fishmeal (LFM) and foreign fishmeal (FFM) grouped as protein sources and wheat offal (WO), brewers' dried grains (BDG), palm kernel cake (PKC) and rice husk (RH) grouped as industrial by-products were collected from feed ingredient dealers in 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 (1) 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.

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

Feed ingredient group	Feed ingredients			
Protein sources	Groundnut cake	Soybean meal	Local fish meal	Foreign fish meal
Industrial by-products	Wheat offal	Brewers' dried grain	Palm kernel cake	Rice husk

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 coarse 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

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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 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 cm3 = 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).

RESULTS AND DISCUSSION

The physical characteristics of protein sources and industrial by-products 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 materials ranges from 0.24-0.45 (g/cm^3), 0.20-1.46 (g water/g feed) and 0.24-0.45 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 (SON, 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.

In the case of feed raw materials, what determine their physical characteristics (BD, WHC and SG) are their nature or physical structures i.e. fibrous nature and the kind of NSPs they are made of- soluble or non-soluble among other factors listed by De Lange (2000). In protein-source group of feed raw materials (Table 2), GNC was similar ($P>0.05$) to all other protein sources in their BD and SG, SBM had the highest BD and was at the same time significantly different ($P<0.05$) from FFM, LLM in BD and SG.

Table 2 - The BD, WHC and SG of protein-source group of feed raw materials

Feed raw Materials	BD (g/cm^3)	WHC (g water/g feed)	SG
GNC	0.37^{ab}	0.20^{b}	0.37^{ab}
SBM	0.45^{a}	1.46^{a}	0.45^{a}
FFM	0.32^{b}	0.38^{b}	0.32^{b}
LFM	0.35^{b}	0.28^{b}	0.35^{b}
SEM	0.0278	0.0981	0.0278

GNC = groundnut cake; SBM = soybean meal; FFM = foreign fish meal; LLM = local fish meal; BD =bulk density; WHC = water holding capacity; SG = specific gravity; ^{ab} means within a column with different superscript are significantly ($P<0.05$) different.

SBM was significantly higher ($P<0.05$) and different in WHC than other protein sources even though it had the highest BD. This is quite different from the results obtained in the commercial feeds where the negative correlation between BD and WHC was maintained. This is a strong indication that SBM may be containing very high quantity of soluble NSPs than other protein sources, making it to hold more water. Hence in using SBM in compounding commercial feed it is important to consider this particular physical quality of SBM and the effect it will have on the quality of the formulated final feed (Kyriazakis and Emmans, 1995).

In the industrial by-products group of feed raw materials (Table 3), WO and PKC were similar ($P>0.05$) in their BD and SG but significantly different ($P<0.05$) from BDG and RH, which were similar ($P>0.05$) to each other in their BD and SG as well. PKC recording the highest BD value also had the highest and significantly different ($P<0.05$) WHC from those of WO, BDG and RH. This is expected because the β-mannan in PKC is likely water soluble. However, in comparison with the BD and WHC of palm kernel meal (PKM) (0.57 g/cm^3 and 2.93 g water/g feed respectively) recorded by Sundu et al (2006), the BD and WHC values recorded here for PKC were relatively low. However, it should be noted that the methods of processing (PKM is solvent extracted while PKC is mechanical extracted) must have influenced the differences in the results obtained between PKC in this study and PKM in Sundu et al. (2006). This phenomenon indicates that PKC has a potential benefit for poultry provided that if included in the diet consumed by birds can be digested and made available to the birds.

Table 3 - The BD, WHC and SG of Industrial by-products feed raw materials group

Feed raw materials	BD (g/cm^3)	WHC (g water/g feed)	SG
WO	0.30^{a}	0.50^{b}	0.30^{a}
BDG	0.24^{b}	0.38^{b}	0.24^{b}
PKC	0.36^{a}	1.29^{a}	0.36^{a}
RH	0.26^{b}	0.29^{b}	0.26^{b}
SEM	0.0264	0.2290	0.0264

WO = wheat offal, BDG = brewers' dried grains, PKC = palm kernel cake, RH = rice husk, 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 protein sources and industrial by-products group of feed ingredients.

In Table 4, GNC, SBM and FFM had significant differences in BD values between ≥1.00 mm PS and <1.00 mm PS. GNC had no significant difference ($P>0.05$) in their BD values between the unmodified PS and < 1.00 mm PS. Similarly, SBM and FFM had no significant differences ($P>0.05$) in its BD values between the unmodified PS and ≥ 1.00 mm PS, while LFM showed significant difference in BD values between the same particle sizes. SBM and FFM maintained a consistency in BD between the unmodified PS and ≥1.00 mm PS. The highest BD was recorded by SBM at ≥1.00 mm PS. Protein sources of fish origin were observed to record lower BD values than those of plant origin.

Table 4 - Particle size effects on BD of some protein sources group of feed raw materials

Feed raw materials	BD (g/cm^3) at different particle sizes			
	Unmodified PS	≥1.00mm PS	<1.00 mm PS	SEM
GNC	0.37^{b}	0.42^{a}	0.30^{b}	0.0348
SBM	0.45^{a}	0.46^{a}	0.38^{b}	0.0251
FFM	0.32^{b}	0.30^{b}	0.33^{a}	0.0088
LFM	0.35^{a}	0.29^{b}	0.32^{ab}	0.0173

GNC = groundnut cake; SBM = soybean meal; FFM = foreign fish meal; LLM = local fish meal; BD = bulk density; WHC = water holding capacity; SG = specific gravity; ^{ab} means within a column with different superscript are significantly ($P<0.05$) different.

The results of particle size effects on WHC of some protein sources group of feed raw materials are shown in Table 5. GNC and FFM recorded significantly higher ($P<0.05$) WHC values in their unmodified PS than in the two modified particle sizes, which were similar (P>0.05) to each other. On the reverse, SBM and LFM recorded significantly higher (P<0.05) WHC values in their finer particles (<1.00mm PS) than in the unmodified PS and ≥ 1.00mm PS, which were statistically similar (P>0.05). There seems to be a kind of WHC grouping among protein sources of feed raw materials in that GNC and FFM had similar results, while SBM and LFM had similar results too. By implication, only one combination of a pair these should be selected in feed formulation. This may help to balance WHC characteristics in the final feed, while combining feed raw materials from different pair may result to synergistic effects on WHC.

Table 5 - Particle size effects on WHC of some protein sources group of feed raw materials

Feed raw materials	WHC (g water/g feed) at different particle sizes			
	Unmodified PS	≥1.00mm PS	<1.00 mm PS	SEM
GNC	0.20^{a}	0.07^{b}	0.10^{b}	0.0392
SBM	1.46^{b}	0.98^{b}	1.68^{a}	0.2066
FFM	0.38^{a}	0.13^{b}	0.33^{b}	0.0763
LFM	0.28^{ab}	0.10^{b}	0.30^{a}	0.0635

GNC = groundnut cake; SBM = soybean meal; FFM = foreign fish meal; LLM = local fish meal; WHC = water holding capacity; ^{ab} means within a column with different superscript are significantly (P<0.05) different.

In SBM however, there was an observed skyrocketing rise in WHC as its particle size was reduced to < 1.00mm PS that was more than 5 times the values obtained in other protein sources at the same finer particle size. This implies that SBM is higher in soluble NSPs than other protein sources used in this study. Hence, in using SBM to formulate feeds of a desired WHC, particle size of the SBM must first be put into consideration as the final WHC of the formulated feeds will depend chiefly on the WHC contributed by individual feed raw materials.

Again, all the WHC values decreased as the particle sizes of the feedstuffs decreased to ≥1.00 mm. This reduction was specifically significant in GNC and FFM (P<0.05). At the <1.00 mm PS, the values rose again beyond those recorded for ≥1.00 mm PS in all cases and were particularly significant for SBM and LFM (Table 5). These results indicate that relatively higher proportions of the unmodified feedstuffs were actually made up by the <1.00 mm PS or fine particles.

To obtain relatively uniform particle sizes for a milled feedstuff, there is the need to determine the milling efficiency of the milling machine used. This is critical since a milling machine of low efficiency may produce feedstuff of varied particle sizes even though it was adjusted to a specific size. Modifying the particle sizes of the feed raw materials reduced the WHC of the feed below their original WHC values and this agrees with Choct (1997), who reported that milling the coarse bran to a particle size of 1 mm almost halved the water holding capacity from 6.15 g to 3.54 g of water per g of bran. Among these feeds, the fish meals (foreign and local) were higher in their WHC values than GNC at all levels of particle sizes. This implies that even protein sources of animal origin incorporated into commercial feeds may be contributors to a high WHC value in such feeds.

However, GNC seemed to be the feed raw material in this group with a very low WHC value and may be very suitable as a protein source in producing feeds with low WHC. This does not remove the fact that the method of oil extraction used in producing the GNC may have also contributed to this WHC in GNC.

In Table 6, GNC, SBM and FFM had significant differences in SG their values for ≥1.00mm PS and <1.00mm PS. GNC had no significant difference (P>0.05) in its SG values between the unmodified PS and <1.00mm PS. SBM and FFM had no significant differences (P>0.05) in its SG values between the unmodified PS and ≥1.00mm PS, while LFM had significant difference in SG values between the same particle sizes. SBM and FFM maintained a consistency in SG between the unmodified PS and ≥1.00mm PS. The highest SG was recorded by SBM at ≥1.00 mm PS. Protein sources of fish origin were observed to record lower SG values than those of plant origin.

Table 6 - Particle size effects on SG of some protein sources group of feed raw materials

Feed raw materials	SG at different particle sizes			
	Unmodified PS	≥1.00mm PS	<1.00 mm PS	SEM
GNC	0.37^{b}	0.42^{a}	0.30^{b}	0.0348
SBM	0.45^{a}	0.46^{a}	0.38^{b}	0.0251
FFM	0.32^{b}	0.30^{b}	0.33^{a}	0.0088
LFM	0.35^{a}	0.29^{b}	0.32^{ab}	0.0173

GNC = groundnut cake, SBM = soybean meal, FFM = foreign fish meal, LLM = local fish meal, SG = specific gravity, ^{ab} means within a column with different superscript are significantly (P<0.05) different.

BDG, PKC and RH had significantly higher (P<0.05) BD values at the unmodified PS than at ≥ 1.00mm PS (Table 7). In WO however, significant difference was observed in WHC values between unmodified PS and the < 1.00mm PS. All industrial by-products group of feed raw materials had similar (P>0.05) BD at both modified particle sizes. It seems there is much effect on BD as particle sizes reduces further. This may be explained by the fact that these feed raw materials have already undergone several industrial processing that may have changed their physical structure and hence, their physical characteristics. Subjecting these feed raw materials of industrial by-products to further processing such as reduction in particle size may not be advisable as this will result to lower

BD which has negative effect on poultry performance (Shelton et al., 2005). Again, the fact that there was no significant PS effect on BD between the ≥1.00 mm and <1.00 mm particle sizes indicates relative uniformity of the unmodified feedstuff sample in its particle size.

Table 7- Particle size effects on BD of some Industrial by-products group of feed raw materials

Feed raw materials	BD (g/cm³) at different particle sizes			
	Unmodified PS	≥1.00mm PS	<1.00 mm PS	SEM
WO	0.30^{a}	0.24^{ab}	0.18^{b}	0.0346
BDG	0.24^{a}	0.18^{b}	0.21^{ab}	0.0173
PKC	0.36^{a}	0.30^{b}	0.30^{b}	0.0200
RH	0.26^{a}	0.18^{b}	0.24^{ab}	0.0240

WO = wheat offal, BDG = brewers' dried grains, PKC = palm kernel cake, RH = rice husk, BD = bulk density, ^{ab} means within a column with different superscript are significantly ($P<0.05$) different.

In Table 8, particle size effects on WHC of the industrial by-products group were reported. BDD, PKC and RH recorded significantly different ($P<0.05$) and higher WHC values at <1.00mm PS than in unmodified PS, while their WHC values at ≥1.00mm PS were similar ($P>0.05$) to the values obtained at unmodified PS and <1.00mm PS.

Table 8 - Particle size effects on WHC of some Industrial by-products group of feed raw materials

Feed raw materials	WHC (g water/g feed) at different particle sizes			
	Unmodified PS	≥ 1.00mm PS	< 1.00 mm PS	SEM
WO	0.50^{b}	1.56^{a}	0.67^{ab}	0.3286
BDG	0.38^{b}	0.67^{ab}	0.73^{a}	0.1080
PKC	1.29^{b}	1.38^{ab}	1.70^{a}	0.1244
RH	0.29^{b}	0.33^{ab}	0.82^{a}	0.1703

WO = wheat offal, BDG = brewers' dried grains, PKC = palm kernel cake, RH = rice husk, WHC = water holding capacity, ^{ab} means within a column with different superscript are significantly ($P<0.05$) different.

However, WO recorded significant difference ($P<0.05$) in WHC values between unmodified PS and ≥1.00mm PS indicating that most of the unmodified WO was in the coarse form. To achieve consistency in WHC in the use of industrial by-products as feed raw materials, it seems particle size should be maintained at ≥1.00mm PS. RH seemed to be the one with the lowest capacity to absorb water. This is expected as RH is mainly fibrous in nature (made of external coating material) than all the rest, however, reducing its particle size to <1.00mm may have provided a larger surface area for maximum absorption of water than WO and BDG at the same PS level. This particle size will give a considerable WHC as it is still observed that apart from WO, other feed raw materials in this group had their WHC increased with decrease in particle size. By assumption, WO may be the most suitable industrial by-product to consider as a feed raw material for feed formulation when WHC is a factor of concern.

From this study, PKC is consistently shown to have the highest natural ability to absorb water. This increased to 1.70 g water/g feed at the <1.00 mm PS. There is the need to study the implication of this in the use of this locally available feedstuff in the sustainable production of commercial poultry diets.

BDG, PKC and RH had significantly higher ($P<0.05$) SG values at the unmodified PS than at ≥ 1.00mm PS (Table 9). In WO however, significant difference was observed in SG values between unmodified PS and the < 1.00mm PS. All industrial by-products group of feed raw materials had similar ($P>0.05$) SG at both modified particle sizes.

Table 9 - Particle size effects on SG of some Industrial by-products group of feed raw materials

Feed raw materials	*SG at different particle sizes*			
	Unmodified PS	≥ 1.00mm PS	< 1.00 mm PS	SEM
WO	0.30^{a}	0.24^{ab}	0.18^{b}	0.0346
BDG	0.24^{a}	0.18^{b}	0.21^{ab}	0.0173
PKC	0.36^{a}	0.30^{b}	0.30^{b}	0.0200
RH	0.26^{a}	0.18^{b}	0.24^{ab}	0.0240

WO = wheat offal, BDG = brewers' dried grains, PKC = palm kernel cake, RH = rice husk, SG = specific gravity, ^{ab} means within a column with different superscript are significantly ($P<0.05$) different.

It seems there is much effect on SG as particle sizes reduces further. This may be explained by the fact that these feed raw materials have already undergone several industrial processing that may have changed their physical structure and hence, their physical characteristics. Subjecting these feed raw materials of industrial by-products to further processing such as reduction in particle size may not be advisable as this will result to lower SG which could have negative effect on poultry performance (Bhatti and Firkins, 1995).

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 Organisation 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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