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Macro-biophysical Properties of Candidate Novel Feedstuffs for Poultry Feeding

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Abstract: Information on the proximate composition and sometimes the toxicology of novel feedstuffs has been used routinely in determining the suitability of feedstuffs in poultry feeding, especially during animal feeding trials. Limited information however exists on the biophysical characteristics of such novel feedstuffs. The Bulk Density (BD), Water-holding Capacity (WHC) and Specific Gravity (SG) of three novel feedstuffs {Leaf Meal (LEM), Rumen Digesta (RD) and Poultry Dung (PD)}, were evaluated. Available published and unpublished results on the proximate compositions of the materials were related to the physical characteristics results. LEM had significantly (p>0.05) lower BD and SG than RD and PD while RD recorded the highest WHC value although the value was similar (p>0.05) to that of LEM. Particle Size (PS) effects showed that BD of RD and PD were lower at the ≥1.00 mm PS than at the unmodified and <1.00 mm PS, indicating that materials of similar Crude Fiber (CF) could be manipulated to yield different BD with possible ultimate effects on the performance of birds. The WHC of LEM at <1.00 mm PS level was seven times higher than that of unmodified and =1.00 mm PS while RD value at the same <1.00 mm PS level was 2 and 4 times higher than those recorded at the unmodified and ≥1.00 mm PS levels, respectively. This is evidence that grinding increased the surface area of the LEM, thus improving the ability of its Non-starch Polysaccharides (NSP) to bind water. Information on the feed physical characteristics could be used together with proximate and toxicological information to determine the nutritional and intake potentials of a novel feedstuff even before a feeding trial.

Key words: Leaf meal, poultry dung, rumen digesta, bulk density, water holding capacity

INTRODUCTION

Poultry production in Nigeria and many developing countries has increased tremendously in the last few decades (Okeudo, 2004). It has been predicted that by 2025, more than 60% of the worlds animal food products derived from poultry, pig and fish will be produced and consumed in the developing countries (Delgado *et al*., 1998). The realization of these projections is predicated predominantly on the continued supply of feed raw materials to these animals, especially from outside the region. The capacity to sustain raw materials supply to the increasing animal food products production industry has thus remained a major constraint of the industry in many developing countries, including Nigeria (Okoli *et al*., 2005). These constraints appear mostly in the form of very high costs of available feed raw materials which in turn, is driven by the competition between man, animals, food and pharmaceutical industries for maize, sorghum and soybean among other conventional feedstufs (Esonu, *et al*., 2004).

In a bid to overcome these constraints, there has been a sustained search for locally available and cheap materials that could replace the highly constrained conventional materials in the feeding of poultry (Udedibie, 2003; Uchegbu *et al*., 2004; Obikaonu *et al*., 2012; Emenalom *et al*., 2004; Madubuike *et al*., 2003; Ucheghu *et al*., 2008; Esonu, *et al*., 2004). Many of the materials tried have given relatively unsatisfactory performance results since in most cases they could not be used beyond 5 to 10% inclusion in poultry diets. These relatively poor results have been blamed on the presence of anti-nutritional substances in the novel feedstuffs (Udedibie, 2003; Esonu *et al*., 2004).

There is currently no clearly developed protocol for selecting local materials of nutritional potentials out of hundreds of candidate raw materials available in a study area. Development of such a selection protocol could eliminate some of the frustrations experienced with many trial materials which usually arise from poor or non-existent selection process. In earlier studies, Okoli *et al*. (2001, 2002 and 2003a) had attempted to use Indigenous Knowledge (IK) as a tool for selecting plants of animal production potentials in southeastern Nigeria and concluded that apart from generating clues to candidate research materials, such studies could promote the development of useful concepts in animal production and encourage the maintenance of bio-cultural diversity.

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Usually feedstuffs have nutritional and toxicological characteristics (Omede, 2008). The nutritional characteristics could be divided into the biophysical and biochemical components that determine nutrient uptake and availability respectively (Emmans, 1989; Okoli *et al*., 2009). Information on the proximate composition and sometimes the toxicology of novel feedstuffs has been used routinely in determining the suitability of such feedstuffs in poultry feeding, especially during animal feeding trials. Limited information however exists on the biophysical characteristics of such novel feedstuffs (Okoli *et al*., 2009).

Biophysical characteristics such as Bulk Density (BD), Water Holding Capacity (WHC), Particle Size (PS) and Specific Gravity (SG) play important roles in controlling feeding (Nir *et al*., 1994; Kyriazakis and Emmans, 1995; Makinde and Sonaiya, 2007) and thus productivity of birds. Kyriazakis and Emmans (1995) noted that WHC is a good predictor of feed intake in pigs compared to feed digestibility and dietary fiber content. This major effect of WHC on digestion is due to the ability of the Non-starch Polysaccharides (NSP) in the feedstuff to hold considerable quantities of water that could increase the bulk and passage rate of digesta (Smits and Annison, 1996).

Previous reports on bulk density implied that lower BD diets resulted to lower body weight in growing chicks (Robertson *et al*., 1948). Knott *et al*. (2004) reported that particle size and PS uniformity of feed ingredients are important considerations for livestock and poultry nutritionists, when selecting resources and determining the need for further processing during the manufacture of complete feeds and feed supplements. This is because PS affects nutrients digestibility, mixing efficiency, pellet quality, incidence of gastric ulcers in swine, palatability, sorting of meal or mash diet and ingredient segregation among others (Nir *et al*., 1994; Knott *et al*., 2004; Omede, 2008). Specific gravity of the feedstuff on the other hand, has an important role in the transit of digesta particles through the gastrointestinal tract of animals as a measure of the biophysical quality of the feed, especially in ruminants (Bhatti and Firkins, 1995).

Since the nutritional characteristics of a finished ration is an aggregation of the proximate, physical and toxicological characteristics of the individual ingredients used in compounding the ration, proper understanding of all these components in all the raw materials used is imperative. Such information could be used in developing protocols for determining the candidacy of a suspected novel feedstuff that could be employed in subsequent animal feeding trials.

This study reports the biophysical characteristics of selected novel feedstuffs at Owerri, Imo state, Nigeria.

MATERIALS AND METHODS

Experimental materials: Four novel feedstuffs (Leaf meal, rumen digesta and poultry dung) were studied. The leaf meal was produced from *Microdesmis puberula* leafs harvested from compound bushes in Ihiagwa, Owerri West Local Government Area of Imo state, Nigeria. The selection, sampling and collection of the experimental materials were carried out using a well planned survey.

About one kilogram of each type of feedstuffs (leaf meal, rumen digesta and poultry dung) was collected from five different locations. Thereafter, each was pooled to form a homogenous sample of about five kilograms of each sample type and stored in properly labeled cellophane bags until needed for analyses.

Particle size (PS) measurement: Three particle sizes were determined using sieve analysis (ASAE, 1983; Jillavenkatesa *et al*., 2001). One kilogram of each experimental sample was measured out, passed through a 1.00 mm mesh sieve to determine coarse and fine particles. 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. Each subset (coarse and fine) was weighed and their weight expressed as percentages of the original weight of the unmodified test sample material.

The unmodified and modified sample sizes were further subjected to bulk density, water-holding capacity and specific gravity measurements in four replications in order to study the effects of particle size on these parameters.

Bulk density (BD) measurement: The method described by Makinde and Sonaiya (2007) and modified by Omede (2010) 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 to obtain the bulk density of the test material. 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) and modified by Omede (2010) 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 the 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 experimental material across different particle sizes.

Specific gravity (SG) measurement: SG was 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.

Proximate composition of test materials: Available published and unpublished results of the proximate compositions of the leaf meal, bovine rumen digesta and poultry dung (Okoli *et al*., 2003b; Azubike, 2010; Nnaji, 2010, respectively) as shown in Table 1 were used to compare the analyses results.

Table 1: Proximate composition of the novel feedstuffs (%)

Raw material	DM	CP	ASH	CF	EE	NFE
LEM*	93.00	25.85	4.80	19.90	6.30	36.15
RD**	94.00	46.10	23.40	6.30	2.13	21.50
PD***	80.00	13.10	24.67	10.64	2.10	20.25

LEM: Leaf meal (*Microdesmis puberula*), RD: Rumen digesta, PD: Poultry dung; DM: Dry matter; CP: Crude fiber; ASH: Ash; CF: Crude fiber; EE: Ether extract; NFE: Nitrogen free extract, Source: *Okoli *et al.* (2003b); **Azubike (2010); ***Nnaji (2010)

Experimental design: The experiment was subjected to a Randomized Completely Block Design (RCBD) to block the error due to variability of sources of the feeds and feedstuffs. The statistical model for the design is given thus:

$$Y_{ij} = \mu+\alpha_i+\beta_j+e_{ij}$$

Where:

- Y_{ij} = jth observation of the i^{th} treatment (feeds and feedstuffs)
- μ = Overall mean
- α_i = Effect of the ith treatment where i = 1, 2, 3…x
- β_j = Effect of the jth block
- e_{ij} = Random error, being normal, independent and identically distributed with men = 0, variance = δ^2

Statistical analyses of data: Data generated on PS, BD, WHC and SG of novel 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

General physical characteristics: Table 2 showed that at the unmodified particle size level, *Microdesmis puberula* leaf meal (LEM) had significantly (p>0.05) lower BD and SG than bovine Rumen Digesta (RD) and poultry dung (PD). RD on the other hand recorded the highest WHC value although the value was similar (p>0.05) to that of LEM. RD and LEM equally recorded higher WHC value than PD.

Particle size effects: There were Particle Size (PS) effects on the physical characteristics of the feed raw materials as shown in the results Table 3-5. The implication of this

Table 2: Bulk density, water holding capacity and specific graduly of the feedstuffs at the unmodified particle size level

Feed raw materials	BD (g/m^3)	WHC (g water/g feed)	SG
LEM	0.02^b	0.61^{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, ^{ab}means within a column with different superscript are significantly (p<0.05) different

Table 3: Particle size effects on BD of the feedstuffs

Feed raw materials	BD (g m^{-3}) at different particle sizes: Unmodified PS	≥1.00 mm PS	<1.00 mm 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, ^{ab}means within a column with different superscript are significantly (p<0.05) different, PS: Particle size

Table 4: Particle size effects on WHC of the feedstuffs

Feed raw materials	WHC (g water/g feed) at different particle sizes Unmodified PS	≥1.00 mm PS	<1.00 mm 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, ^{ab} means within a column with different superscript are significantly (p< 0.05) different

Table 5: Particle size effects on SG of the feedstuffs

Feed raw materials	SG at different particle sizes Unmodified PS	≥1.00 mm PS	<1.00 mm 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, ^{ab}means within a column with different superscript are significantly (p<0.05) different

effect is that particle size could determine the physical characteristics of a feed raw material used in formulating a feed irrespective of its proximate values. The final feed formulated with the same feed raw material may yield different physical characteristics because of variations in particle size levels being used.

LEM had significantly higher (p<0.05) BD value at the <1.00 mm PS than at the ≥1.00 mm and unmodified PS levels (Table 3). The BD of RD and PD were lower at the ≥1.00 mm PS than at the unmodified and <1.00 mm PS indicating probably that the materials at their unmodified states were made up of mostly fine particle sizes (<1.00 mm). This indicates that even though the CF of the materials may remain the same, their densities could be manipulated to suit the desire of the feed formulator, with possible ultimate effects on the performance of birds.

In their WHC as shown in Table 4, all the test 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. LEM, at the ≥1.00 mm PS however, recorded similar (p>0.05) WHC value to other two particle sizes. Specifically, LEM's WHC at the <1.00 mm PS was more than seven times higher than those of unmodified and ≥1.00 mm PS while RD value at the <1.00 mm PS level was 2 and 4 times higher than those recorded at the unmodified and 1.00 mm PS levels, respectively.

All Novel the feedstuffs had significantly higher (p<0.05) SG values at the <1.00 mm PS than at ≥1.00 mm PS (Table 5). Furthermore, significant differences (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 the two modified particle sizes. Again, SG and BD values, followed a similar particle size effects trend as BD of the test materials.

DISCUSSION

From the present results, the leaf meal (LEM) seems to have more fibrous matter than the rest of the feedstuffs while Poultry Dung (PD) would have lower fibrous content for it to record the highest BD. The actual Crude Fiber (CF) value of the LEM and PD as shown in Table 1 agrees with the physical analyses data. However, the 6.30% CF reported in table 1 for RD (Azubike, 2010) does not support our BD result. Such a relatively low CF material is expected to record a higher BD value than PD. Azubike (2010) also reported a much higher CF value of 21.9% for the same bovine rumen digesta other sources which expectedly would yield BD value similar to the one obtained in this study. It is probable that seasonal variations in the fibrous nature of the tropical grasses grazed by cattle in the study area are responsible for these wide differences. Most Nigerian slaughter cattle originate from the northern parts of the country where dry season fodder are mostly dried grasses, hay and stovers. Previous reports on bulk density implied that lower BD diets resulted to lower body weight in growing chicks (Robertson *et al*., 1948; Shelton *et al*., 2005).

Rumen digesta recorded the highest water holding capacity value in the unmodified samples as shown in Table 2. It is probable that the microbial activities in the rumen of cattle from which RD were obtained helped to breaking it down, thus exposing its surfaces to better water absorption. Again, the WHC results seem to suggest that LEM and RD contain higher quantities of water soluble Non-starch Polysaccharides (NSP) than the PD.

Since the SG values in this study were derived mathematically from the BD values, the recorded similar trends of SG and BD of the test materials (Table 2) is expected. While the rest of the feed may have the tendency to remain longer in the lumen of the intestine of birds because of low SG, PD may not and hence would be a better material in that regard. The low SG values of LEM and PD may be overcome by pelleting final feeds in which they are included at high levels. The implication of low SG is low retention time and faster passage of feed particles in and through the GIT respectively (Bhatti and. Firkins, 1995).

In many feed raw materials, what determines physical characteristics such as BD, WHC and SG is the nature or physical structure of the material (fibrous nature and the kind of NSPs they are made of which may be soluble or non-soluble) among other factors listed by De Lange (2000). This means that for a proper ranking of the nutritional value of novel feedstuffs to be developed, there is the need for further physical quality characterization. At present however, research attention is focused more on biochemical and replacement values novel feedstuffs for conventional feed raw materials (Omede, 2010).

Particle size has been shown to affects nutrients digestibility, mixing efficiency, pellet quality, incidence of gastric ulcers in swine, palatability, sorting of meal or mash diet and ingredient segregation among others (Nir *et al*., 1994; Knott *et al*., 2004; Omede, 2008). The WHC of LEM at <1.00 mm PS level was seven times higher than that of unmodified and 1.00 mm PS while RD value at the same <1.00 mm PS level was 2 and 4 times higher than those recorded at the unmodified and 1.00 mm PS levels, respectively. Therefore, grinding might have increased the surface area of the LEM used in this study, thus improving the materials' ability to bind water. In addition, the results reflect the degree of soluble NSP that may be contained in the LEM and RD. Kyriazakis and Emmans (1995) noted that WHC is a good predictor of feed intake in pigs compared to feed digestibility and dietary fiber content. This major effect of WHC on digestion is due to the ability of the Non-starch Polysaccharides (NSP) in the feedstuff to hold considerable quantities of water that could increase the bulk and passage rate of digesta (Smits and Annison, 1996).

These alterations in WHC of LEM and RD across particle size levels highlights the considerable effects possessing could have on a feed stuff and its utilization which may not be captured by proximate analysis. However, the SG values obtained in this study were very low. The materials may likely float within the GIT of monogastric animals if fed as single diets as none of the feed raw materials had SG value up to 1.2 which was the minimum feed particle SG suggested by Kaske *et al.* (1992) and Bhatti and Firkins (1995).

Recently attempts have been made to develop mathematical models for predicting influence of physical characteristics feed raw materials on finished feed. Omede (2010) physical characteristics values for feed raw materials were 70.36, 96.64 and 96.26% correct for predicting bulk density, water holding capacity and quantity of water absorbed, respectively. He also showed the existence of relationships between the bulk density of commercial broiler starter feeds and the water holding capacity of feed raw materials at ≥1.00 mm particle size. He also showed that at the same particle size, relationship exists between their water holding capacity while at the unmodified particle size; there was a relationship between their bulk density.

CONCLUSION

This study has shown that information on the physical characteristics such as bulk density, water holding capacity and specific gravity are of critical importance in determining the actual value of a novel feedstuff. Such information could be used together with proximate and toxicological information need to determine the actual potential of a novel feedstuff even before a feeding trial.

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