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Digestibility and Nutrient Utilization of Some Agro-Industrial By-Products Fed to Growing Pigs in the Humid Tropics

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Abstract: Digestibility and nutrient utilization of some agro-industrial by-products fed to growing pigs in the humid tropics were determined with twelve castrated male hybrid (Large White x Landrace) pigs whose weights ranged from 15.33 to 17.67 kg (average 16.17 kg) and aged 13 weeks. The experimental design was a Completely Randomized Design (CRD). Each of the four treatments had three replicates and a castrated male per replicate. Locally constructed metabolism cages (107 cm x 60 cm x 50 cm) were used in the experiment. Parameters measured were nutrient intake, digestibility coefficients of DM, CP, CF, Ether Extract and Nitrogen Free Extract (NFE). Others were energy utilization, nitrogen (N) balance and protein utilization. Wheat offal fed to growing pigs significantly ($P<0.05$) increased DM (418 g) and organic matter (391 g) intakes but significantly depressed apparent digestibility coefficient of ether extract (67.50%) and nitrogen intake (16.00 g). Other nutrient and energy utilization indices were not significantly ($P>0.05$) affected. The conclusion was that Palm Kernel Meal (PKM), Brewers Dried Grain (BDG), wheat offal or equal proportions of PKM+BDG fed to growing pigs have similar apparent nutrient digestibility coefficients, energy utilization, nitrogen balance and protein utilization. However, wheat offal could decrease digestibility coefficient of Ether Extract (EE) and also nitrogen intake.

Key words: Industrial by-products, energy utilization, nitrogen balance, growing pigs

INTRODUCTION

Pig production is important in the humid tropics of Nigeria (Southern States) where pork is accepted and relished. Due to high cost of conventional feed ingredients like maize, soybean meal and fish meal, most pig farmers resort to feeding their pigs with mainly agro-industrial by-products such as Palm Kernel Meal (PKM), Brewers Dried Grain (BDG), wheat offal and or other wastes. The farmers use these by-products without sufficient knowledge of their nutritional value in terms of nutrient content, digestibility and nutrient availability.

Palm Kernel Meal (PKM) is obtained after extracting most of the oil from palm kernels. The extraction method used (either solvent or hydraulic press) determines the level of residual oil left after extraction, which eventually affects the proximate composition and quality of the PKM. It is readily available and cheap, containing 14-21% crude protein and 10-20% crude fibre (Onwudike, 1986; Olomu, 1995). PKM depressed feed intake and live weight gain of finisher pigs when included up to 32% DM of the diet (Babatunde *et al.*, 1975) and similarly at 18.80-46.50% of the entire diet (Fetuga *et al.*, 1977). Jegede *et al.* (1994) reported that final weight of pigs decreased linearly as the level of PKM increased in a diet from 20.55 to 61.65% with no significant effect on dressing percentage and other carcass characteristics.

Brewers Dried Grain (BDG) is solid waste from the brewery industries. It is available and cheap but difficult to dry to low moisture content for easy storage and use, especially during the wet seasons. There is wide variability in the proximate composition of BDG depending on the brewery that produced it (Oyediji, 2001). Breweries in Nigeria presently use maize and sorghum in combinations, which vary from one brewery to another (Oluponna *et al.*, 2002). This, therefore, has resulted in the production of BDG with variable physical and chemical composition (Oluponna and Balogun, 1996). BDG contains about 19-25% crude protein (Kwari *et al.*, 1999; Oluponna *et al.*, 2002), 10-22% crude fibre (Kwari *et al.*, 1999; Oluponna *et al.*, 2002), ME of 7.38 MJ/kg (Dogari, 1985) and gross energy value of 3030-3170 kcal/kg (Oluponna *et al.*, 2002).

Wheat offal is a by-product of wheat after obtaining flour for human use. Wheat offal is made up of wheat germ, bran (greatest proportion of the wheat offal), coarse middling and fine middling (Alawa and Umunna, 1993). Wheat offal contains 14.80-17.60% CP (Maisamari, 1986; Yin *et al.*, 1993; Olomu, 1995), about 10% crude fibre (Olomu, 1995) and 3.4-6.40% crude ash (Maisamari, 1986; Yin *et al.*, 1993; Olomu, 1995). The lower crude fibre content when compared to BDG and PKM makes wheat offal suitable for feeding monogastric animals (Alawa and Umunna, 1993).

These agro-industrial by-products may have undergone changes in their proximate and nutrient composition with time due to changes in the variety of crops used in producing them and methods of industrial processing.

There is also the need to establish the bioavailability of nutrients from these by-products for pigs to ensure adequate feeding and at a low cost too. The objective of this study, therefore, was to determine the digestibility and nutrient utilization of Palm Kernel Meal (PKM), Brewers Dried Grain (BDG), wheat offal and equal proportion of PKM+BDG fed to growing pigs in the humid tropics.

MATERIALS AND METHODS

Location of study and source of ingredients: The research was conducted at the Piggery Unit of the Teaching and Research Farm of Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Brewers dried grain was obtained from Nigerian Breweries, Aba, Abia State; wheat offal from Calabar Flour mill, PKM from a company in Aba that uses hydraulic press method for oil extraction from palm kernels and pigs from the University Farm.

Experimental pigs and their management: The digestibility and nutrient utilization of Palm Kernel Meal (PKM), Brewers Dried Grain (BDG), wheat offal and PKM+BDG were determined with 12 castrated male hybrid (Large White x Landrace) pigs whose live weights ranged from 15.33 to 17.67 kg (average 16.17 kg) and aged 13 weeks. The pigs were put individually in a metabolism cage (107 cm x 60 cm x 50 cm) locally designed and constructed with wood for this purpose. The cage floor was strong expanded metal gauze covered on top with net. The height of the cage from the ground was 60 cm. The feed and water trough areas of the cages were each 30 cm x 30 cm x 27 cm. The metabolism cages were placed inside one of the Piggery houses. There were three cages in a pen measuring 3.95 m x 2.96 m. the feeding and water troughs areas were fitted with stainless bowls tightly secured to prevent pigs from pouring away feed and water. The cage floor was covered with metal wire net for easy and total faecal collection, while an aluminum sheet placed underneath the cages served for urine collection. Urine was channeled through a plastic funnel containing a spongy sieve into a plastic container that was properly labeled.

Diets and feeding: Each feedstuff was fed to the pigs at the daily rate of 3.15% of live weight in line with the procedure of Norachack *et al.* (2004). The diets were milled to pass through a 2 mm sieve, thoroughly mixed to obtain uniform composition and supplemented with 2.0% bone meal. This was to prevent mineral deficiency. Water was provided to the pigs *ad libitum* throughout the period of the experiment.

Experimental design and data collection: The Experimental design was Completely Randomized Design (CRD). There were four treatments; each replicated three times, with one castrated male pig constituting a replicate. The pigs were kept in the cages for nine days to acclimatize before data collection began. This also enabled the technical assistants get used to the protocol of the experiment.

The pigs were starved for 12 hours prior to the experimental feeding to clear the gut of the previous meals, especially as markers were not used. They were also starved for another 12 hours at the end of the feeding period to ensure total collection of faeces arising from the diets offered.

Faeces and urine were collected separately on a daily basis every morning (7.30-8.30 am). The faeces were oven dried at 60°C, weighed and put in a labeled plastic bag and stored in a deep freezer. Urine was also collected three times (7.00 am, 12.00 noon and 5.00 pm, local time) daily in a labeled plastic container, with the record of the total weight and volume. About 10% of each day's collection was stored in 10 mL of 10% sulphuric acid to prevent nitrogen losses by evaporation of ammonia and help keep the urine pH below 4. The urine was stored in a deep freezer until required for analysis. At the end of 7 days collection period, faeces from each replicate were mixed, ground representative samples taken for proximate composition determination. The urine from each replicate was also mixed together and representative samples taken for nitrogen determination.

Chemical and data analyses: Proximate composition of test ingredients, faeces and nitrogen in urine were determined according to the method of A.O.A.C. (1990). The Gross Energy (GE) of test ingredients and faeces were calculated from the proximate components according to the equation of Ewan (1989):

$$GE = 4143 + (56 \times \%\ EE) + (15 \times \%\ CP) - (44 \times \%\ Ash);\quad R^2 = 0.98.$$

Where:

GE = Gross energy (kcal/g);
EE = Ether extract;
CP = Crude protein (N x 6.25);
Ash = Crude ash

Dietary GE intake minus the GE of faeces gave Digestible Energy (DE). Metabolizable Energy (ME) intake was calculated as 96 percent of DE (Farrell, 1979; Agricultural Research Council, 1981; National Research Council, 1998). The factor used for the correction of ME to nitrogen equilibrium (MEn) was 7.83 kcal/ g according to Wu and Ewan (1979). The equations of Close and Menke (1986) were adapted in calculating Biological Value (BV) and Net Protein Utilization (NPU) as follows:

BV = N intake- (Faecal N-FNe) - (Urinary N-UNe) (P > 0.05) x 100

N intake-(Faecal N-FNe)

Where:
Fne = endogenous N losses in faeces;
Une = endogenous N losses in urine.

NPU = BV x IN - FN - Fne (P > 0.05)

IN

Where:
IN = Nitrogen intake;
FN = faecal nitrogen.

Data obtained were subjected to analysis of variance (ANOVA) for a completely randomized design (Steel and Torrie, 1980). The values in percentages were subjected to Arcsine transformation before ANOVA, while differences between treatment means were separated with Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

The proximate components of Palm Kernel Meal (PKM), Brewers Dried Grain (BDG) and wheat offal used in the study are presented in Table 1. BDG had the highest CP, Ether Extract (EE) and Crude Fibre (CF) contents of 22.49, 6.25 and 21%, respectively. It also had the highest Gross Energy (GE) value of 19.34 MJ/kg while wheat offal had the lowest value of all the proximate components and energy, except crude ash content.

The Dry Matter (DM) intake of the growing pigs (Table 2) from PKM, BDG, wheat offal and PKM+BDG ranged from 409 to 418 g/d. Wheat offal gave a significantly (P<0.05) higher DM intake than BDG, PKM+BDG and PKM in that order. This DM intake pattern of growing pigs did not significantly (P>0.05) affect DM intake as a percentage of Body Weight (BW), faecal DM and DM retention but significantly (P<0.05) influenced Organic Matter (OM) intake, which followed the same pattern as DM intake.

There were no significant (P>0.05) differences among the test ingredients in digestibility coefficients of DM, OM, CP, CF, Nitrogen Free Extract (NFE) and energy (Table 2), although wheat offal had higher numerical values than PKM, BDG and PKM+BDG in all the nutrient digestibility coefficients except ether extract. Digestibility coefficient of EE of wheat offal (67.50%) was significantly (P<0.05) lower than that of BDG (84.14%) only.

Energy utilization parameters measured did not significantly (P<0.05) differ among the test feed ingredients fed to growing pigs (Table 3). However, PKM had higher numerical values for DE (7.03 $MJkg^{-1}$), ME (6.75 $MJkg^{-1}$) and MEn (6.72 $MJkg^{-1}$).

Nitrogen (N) balance and protein utilization of PKM, BDG, wheat offal and PKM+BDG by growing pigs is presented in Table 4. Apart from significantly (P<0.05) reduced N intake (16 g/d) by pigs fed wheat offal than other test feed ingredients, the feed ingredients did not differ in N balance and protein utilization measured. However, N retention as percentage of intake, digested N, Biological Value (BV) and Net Protein Utilization (NPU) were numerically higher with wheat offal.

Table 1: Proximate and energy composition of Palm kernel meal, Brewers dried grain and Wheat offal fed to growing pigs

Composition*	PKM	BDG	Wheat offal
Dry matter (%)	89.70	89.50	90.00
Crude protein (%)	20.53	22.49	18.74
Ether extract (%)	6.15	6.25	4.35
Crude fibre (%)	16.25	21.00	7.00
Crude ash (%)	4.30	4.70	5.80
Nitrogen free extract (%)	42.47	35.06	54.11
Gross energy ($MJkg^{-1}$)	19.27	19.34	18.46

PKM = Palm kernel meal; BDG = Brewers dried grain. *DM basis

Proximate composition: The proximate compositions of PKM, BDG and wheat offal obtained in this study are in line with the values reported by Maisamari (1986), Olomu (1995) and Kwari *et al.* (1999). One of the characteristic features of the agro-industrial by-products is the variability in their proximate and nutrient composition (Olomu, 1995), which could be due to differences in crop variety and methods of product processing. The higher CP and fat contents of BDG could have been due to fermentation and use of maize and/ or sorghum by the breweries in producing their products.

Nutrient intake and apparent digestibility: The effect of feeding single agro-industrial by-products like PKM, BDG, wheat offal and/or their combinations on DM and OM intake and utilization is not widely reported in literature. However, the higher DM and OM intake from wheat offal may be due to lower crude fibre content (7%) compared to PKM (16.25%) and BDG (21%). The inability of DM intake to influence DM as percent of BW, DM and OM retention suggests that for growing pigs, DM and OM retention is not affected by intake but by some other factors unknown to us.

The report of apparent digestibility coefficients of nutrients of most agricultural by-products found in Nigeria that usually contain high dietary fibre is also scanty. Fibre has been identified as one of the most important factors that affect digestibility indices in pigs (Jorgensen *et al.*, 1996). The digestive utilization of Dietary Fibre (DF) varies with its botanical origin (Chabeauti *et al.*, 1991). In this connection, the non-significant difference in faecal digestibility coefficients of DM, OM, CP, Crude Fibre (CF) and energy among the feed ingredients suggests that they contain CF of similar biochemical characteristics, especially cell wall constituents. Although, we did not determine the cell wall

Table 2: Nutrient Utilization and Apparent Nutrient Digestibility Coefficients of PKM, BDG, wheat offal or PKM+BDG by Growing Pigs

Nutrient	PKM	BDG	Wheat offal	PKM+BDG	SEM
Live weight (kg)	17.67	16.33	15.33	15.33	1.35
Dry matter (DM) intake (g)	409.40[d]	411.70[b]	418.60[a]	410.55[c]	0.03
DM intake as % of BW	2.35	2.55	2.78	2.71	0.22
Faecal DM (g)	108.38	112.83	105.98	153.63	22.07
DM retention (g)	301.02	298.87	312.62	256.92	22.07
OM intake (g)	389.62[d]	390.08[b]	391.92[a]	389.85[c]	0.03
Faecal OM (g)	87.03	88.10	75.46	115.23	18.47
OM retention (g)	302.59	301.98	316.46	274.62	18.47
Digestibility Coefficients					
Dry matter (%)	73.53	72.59	74.68	62.28	3.38
Organic matter (%)	77.66	77.41	80.74	70.44	4.74
Crude protein (%)	85.07	80.43	85.17	76.16	2.35
Crude fibre (%)	68.80	57.10	69.35	47.10	5.40
Ether extract (%)	79.84[ab]	84.14[a]	67.50[b]	73.66[ab]	3.10
NFE (%)	75.46	78.33	82.91	71.23	3.72
Digestible Energy (%)	78.83	78.46	80.12	71.47	2.93

a,b Means in a row with different superscripts are significantly different (P<0.05). OM = Organic matter. SEM = Standard error of mean. NFE = Nitrogen free extract. PKM = Palm kernel meal; BDG = Brewers dried grain

Table 3: Energy Utilization of PKM, BDG, Wheat offal or PKM+BDG by growing pigs

Energy ($MJkg^{-1}$)	PKM	BDG	Wheat offal	PKM+BDG	SEM
GE intake	8.92	8.90	8.58	8.91	0.45
Faecal GE	1.89	1.92	1.71	2.54	0.38
DE intake	7.03	6.98	6.87	6.37	0.38
ME intake	6.75	6.70	6.60	6.11	0.37
MEn	6.72	6.67	6.57	6.08	0.37
ME:DE ratio (%)	96.02	95.99	96.07	95.92	-
ME as % of GE	76.10	75.55	77.00	68.70	2.70

SEM = Standard error of mean. PKM = Palm kernel meal. BDG = Brewers dried grain. GE, DE, ME and MEn = Gross energy, Digestible energy, Metabolizable energy and Metabolizable energy corrected for nitrogen, respectively

Table 4: Nitrogen Balance and Protein Utilization of PKM, BDG, Wheat offal or PKM+BDG by growing pigs

Nitrogen Balance (g/d)	PKM	BDG	Wheat offal	PKM+BDG	SEM
N intake	16.58[a]	16.55[a]	16.00[b]	16.57[a]	0.05
Faecal N	2.48	3.24	2.37	3.95	0.53
N in urine	3.70	5.40	3.42	4.46	0.58
Digested N	14.10	13.31	13.63	12.62	0.53
N retention	10.40	7.91	10.20	8.15	0.79
Retention as % of					
Intake	62.48	47.79	63.77	49.21	4.78
Digested N	73.77	59.47	74.81	64.21	4.61
Biological value (%)	74.41	60.49	75.45	65.14	2.91
NPU	64.74	49.82	65.89	51.22	4.80

a,b Means in a row with different superscripts are significantly different (P<0.05). OM = Organic matter. SEM = Standard error of mean. PKM = Palm kernel meal; BDG = Brewers dried grain. N = Nitrogen, NPU = Net Protein utilization

constituents and their faecal digestibility coefficients, it is possible that the high CF (Samkol *et al*., 2002) and their cell contents (Ly *et al*., 2001; Hogbergand and Lindberg, 2006) may have had a negative influence on digestibility coefficient of DM, OM and other nutrients of the ingredients (Le Goff and Noblet, 2001), especially PKM and BDG. This could explain why wheat offal had numerically higher nutrient digestibility coefficient values than PKM and BDG, except ether extract. Hansen *et al*. (2007) have also indicated that fibre influences the excretion of nitrogen by repartitioning nitrogen from urine to faeces.

The differences in fat digestibility coefficients between wheat offal and BDG could suggest that fat from wheat offal may contain fatty acids of higher chain length and degree of unsaturation (Kidder and Manners, 1978), which reduces fat digestibility. Jorgensen *et al*. (1983) had stated that the binding of fat by minerals reduces crude fat digestibility, especially calcium reaction with fatty acids (Pallauf and Huter, 1993). Generally, the determination of fat digestibility in pigs is complicated by appreciable quantities of endogenous fat that enters into the small intestine as a component of lecithin in bile (Kidder and Manners, 1978). Microbial activity (hydrogenation of unsaturated fatty acids) in the caecum and large intestine as well as crude fibre content also affect crude fat digestibility (Just, 1982).

The digestibility coefficient of energy (DCe) obtained in our study varied between 71 and 80%, which is in line with the report of Noblet and van Milgen (2004) that DCe varies between 70 and 90% and larger variation (0 to 100%) for feed ingredients (Sauvant *et al*., 2002). They attributed the variations to Dietary Fibre (DF) defined as non-starch polysaccharides and lignin.

Energy utilization: According to Noblet and van Milgen (2004), *ad libitum* energy intake in growing pigs depends on many animal (BW, genotype, sex, health) and environmental (climate, housing system, pig density, feed characteristics) factors. In our study, the pigs had similar characteristics of BW (Table 2), genotype and sex. The environmental conditions were also the same, except feed (test feed ingredients) characteristics, which may have accounted for the minor differences observed in energy intake of the pigs, fed the different test ingredients. Although, wheat offal had a lower GE content (Table 1), it did not result in a significant difference in energy intake and utilization of pigs, confirming that daily energy intake remains relatively constant across diets with different energy densities (Noblet and van Milgen, 2004). High residual oil of PKM (oil extracted with a hydraulic press machine) used in this study may have contributed to its numerically higher energy content.

The similar DE intake among growing pigs fed the test ingredients suggest that they have similar DF characteristics and physicochemical properties (Noblet and Le Goff , 2001; Noblet and van Milgen, 2004). The DE, ME and MEn obtained in our study (Table 3) indicate that growing pigs have the ability to digest DF from the test ingredients (especially, PKM and BDG) and obtain enough energy for normal physiological functions and growth. However, the combination of PKM and BDG in equal proportions gave a higher faecal energy, which resulted in a numerical lower DE, ME and MEn intake by pigs. This could be attributed to the inability of microbial population in the large intestine and caecum to ferment the DF of PKM+BDG (Kidder and Manners, 1978) and possible interaction between the biochemical components of the two ingredients.

The ME:DE ratio of 96% (Table 3) obtained for our feed ingredients is in line with the report (0.96) of Noblet and van Milgen (2004), especially as the CP of the feed ingredients did not exceed 25% (range 18.74 to 22.49%) as shown in Table 1.

Nitrogen balance and protein utilization: Wheat offal significantly depressed N intake of pigs due to its lower CP content (Table 1). But this could not affect nitrogen balance and protein utilization indices of the growing pigs, suggesting that the differences in N intake were of no biological importance (Amaefule *et al*., 2006). While the feed ingredients did not give significant differences in N balance and protein utilization indices of pigs, there was no regular pattern in the numerical (non-significant) differences in the indices, suggesting that the feed ingredients were the same in protein quality.

Conclusion: Palm Kernel Meal (PKM), Brewers Dried Grain (BDG), wheat offal or equal proportions of PKM and BDG fed to growing pigs have similar apparent nutrient digestibility coefficients, energy utilization, nitrogen balance and protein utilization. But it should be expected that wheat offal would increase DM and OM intakes and decrease digestibility coefficient of Ether Extract (EE) and also nitrogen intake.

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