Comparative Evaluation of Carcass Cut and Meat Quality of Finisher's Pigs Fed Rice Offal and Millet Hulls Base Diets

***Akhigbe, O, Ojinnaka, P.E, Omotoso O. B and Yakubani, B.**
Department of Animal Production and Health,
Federal University Wukari, Taraba State
*josephoses12@gmail.com
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Abstract
This research was to comparatively evaluate the meat quality including the pH, water holding capacity of pork and the proximate analysis of specific pork cuts of finisher's pigs fed rice offal's and millet hulls based diets . The study was carried out at the Swine unit of Teaching and Research Farm of the Department of Animal Production and Health, Federal University Wukari, Taraba State. Eighteen (18) mixed local breeds of grower's pigs. After slaughter, the proximate composition of raw blade shoulder, hind limb and bacon of pig breeds was analyzed. The water holding capacity for the hind limb, T_1 had the highest value with 28.65 and had a calcium level of 11.45 in T_2 . There was no significant differences in the crude protein across all treatments in the blade shoulder with values of 22.11 for T_1,23.56 for T_2 and 23.56 for T_3. The ether extract recorded 5.51 for T_1 had the highest value. The value for potassium in T_1 was also the highest with a value of 209.78 and phosphorus had a value of 259.34 for T_3. For the pork belly, the crude protein had no significant difference with values for T_1 with 23.45, T_2 having 23.23 and T_3 with similar value of 23.23. However, T_1 had the highest value for ether extract with a value of 5.560 in T_1. The result for cook loss in T_3 had the highest value with 23.560 and a water holding capacity of 27.45.

Introduction
Pig farming is the raising and breeding of domestic pigs as livestock. Pigs are reared principally for food and raw materials such as pork, bacon, ham, gammon and skins (*Flisser, et al., 2011*). Historically, pigs were kept in small numbers and were closely associated with the residence of the owner (Lander, *et al.,* 2020). They were valued as a source of meat and fat, and for their ability to convert inedible food into meat and manure, and were often fed household food waste when kept on a homestead. Pigs are a popular form of livestock, with more than one billion pigs butchered each year worldwide, 100 million of them in the United States of America (USA), (Hemsworth, 2003 and Hemsworth *et al.,* 2000). Pigs are farmed in many countries, though the main consuming countries are in Asia, meaning there is a significant international and even intercontinental trade in live and slaughtered pigs. Despite having the world's largest herd, China is a net importer of pigs, and has been increasing its imports during its economic development. The largest exporters of pigs are the United States, the European Union, and Canada. As an example, more than half of Canadian production (22.8 million pigs) in 2008 was exported, going to 143 countries (Canadian Pork Exports, 2018). Older pigs will consume eleven to nineteen litres (three to five US gallons) of water per day. Pigs have a lower feed conversion ratio than cattle, which can provide an advantage in lower unit price of meat because the cost of animal feed per kilogram or pound of resultant meat is lower (Thorne and Peter, 2017).

However, there are also many other economic variables in meat production and distribution, so the price differential of pork and beef at the point of retail sale does not always correspond closely to the differential in feed conversion ratios. According to Ewan, (2001) total production costs in the swine-based industry have largely corresponded to the feed costs, making it lose out on nearly 70% of profits. The energy content of the basal diet is a major determinant of pig performance and is the most expensive part of the diet's cost. Corn–soybean meal (SBM)-based diets are both common energy and protein sources for swine diets in South Korea. The non-starch polysaccharides (NSP) in corn–SBM-based diets can negatively affect the performance, which in turn can have serious consequences for the profitability of the pork industry (Omogbenigun *et al.,* 2004 and Van Kempen *et al.,* 2006). Corn contains 0.9% soluble and 6% insoluble NSP, while soybean contains 6% soluble and 18% to 21% insoluble NSP according to (Bach *et al.,* 1991) and Summers, (2001). Therefore, an increasing consideration is paid on enzyme utilization in livestock nutrition. Exogenous enzyme supplementation is used to target NSP and protein, consequently improving digestion, weight gain in monogastric animals fed corn–SBM diets (Kim *et al,.* 2006 and Fang *et al.,* 2007) and absorption of nutrients such as energy and protein, while reducing feed costs. Increasing dietary energy from added enzyme has been consistently shown to be able to improve growth performance and feed efficiency from the middle to nursery period (Jo *et al.,* 2012). Feeding strategy is the most actively used management tool for controlling quality in meat production, animal performance, and eating (Andersen *et al.,* 2005). Pigs are usually restricted-fed in order to control the quality of the pork, as the pig has the tendency of eating more feed than it can put to good use leading to a fatty carcass (Schiavon *et al.*, 2015) Fermented cassava products have also been used severally as alternative feed sources for many livestock species with cost-reducing benefits (Udedibie *et al.,* 2004; Ekpo *et al.,* 2009). There is however little information on the effects of the use of rice offal and Millet hulls wastes on meat quality and carcass characteristics of farm animals and especially of pigs, to this effect, this study was conceived.

Materials and methods

Location of the study

The study was carried out at the Swine unit of Teaching and Research Farm of the Department of Animal Production and Health, Federal University Wukari, Taraba State. Wukari is located at longitude 9°47'0" E and latitude 7°51' 0" N longitude 9°47'0" E. The vegetation of the area is predominantly characteristics of savannah zone and with major climatic seasons of wet or rainy seasons, which starts in March or April, and ends in October and the dry season which starts in November and ends in March or April (Taraba State Dairy, 2008).

Experimental Diets

Three dietary treatments were compounded using rice offals and millet hulls. Diet 1 will serve as control containing 100% maize offals while diets 2 were contain 100% rice offals, and diet 3 were contain 100% millet hulls inclusion levels respectively.

Experimental Design and Animal Management

Eighteen (18) mixed local breeds of growers' pigs with an initial weight of 26.83kg were sourced within Wukari metropolis. The pigs were divided into three treatment groups of six animals per group replicated three times in a completely randomized design. Each pen were provided with feeders, drinkers and wallow. Animals were dewormed before the commencement of the experiment. The animals were fed *ad libitum* and the experiment lasted for 56 days. And the final weight as slaughter is 80.07±01.

Table 1 Ingredient Composition of Experimental Diets

	Dietary treatments		
Ingredients	T1	T2	T3
Maize	48.00	48.00	48.00
Soyabean meal	25.00	25.00	25.00
Maize offal	25.00	0.00	0.00
Rice offal	0.00	25.00	0.00
Millet hulls	0.00	0.00	25.00
Bone meal	1.00	1.00	1.00
Methionine	0.30	0.30	0.30
Lysine	0.20	0.20	0.20
*Premix	0.20	0.20	0.20
Salt	0.30	0.30	0.30
**Enzyme	0.00	0.20	0.20

*premix composition (per kg of diet): vitamin A, 12500 IU; vitamin D_3, 2500 IU; vitamin E, 50.00 mg; vitamin K_3, 2.50 mg; vitamin B_1, 3.00 mg; vitamin B2, 6.00 mg; vitamin B_6, 6.00 mg; niacin, 40 mg; calcium pantothenic, 10 mg; biotin, 0.08 mg; vitamin B^{12}, 0.25 mg; folic acid, 1.00 mg; chlorine chloride, 300 mg; manganese, 100 mg; iron, 50 mg; zinc, 45 mg; copper, 2.00 mg; iodine, 1.55 mg; cobalt, 0.25 mg; selenium, 0.10 mg; and antioxidant, 200 mg
** Enzyme composition per kg diet: amylase 110,000units, cellulose 500,000.00units, xylanase 1,000,000units, lipase 10,000units, pactinase 30,000.0units and 4,000 units.

Carcass Sampling of Pigs
Procedure for Slaughtering Pig

1. Animals were stunned thereby rendering the pig unconscious before the jugular vein of the animal was severed.
2. Bleeding of the animal was done by hanging.
3. Scalding was carried out by immersion of the slaughter pig into hot water and using of knife or razor blade to scramp the hair.
4 Evisceration was achieved by the removal the internal Organs carefully using a knife.

Water Holding Capacity Determination

Drip loss method

This water holding capacity can be determined by using the suspension method of Honikel. Each muscle was sliced to 2.0-cm in thickness, and processed into a disk with a diameter of 4 cm. Samples will be put into netting and suspended in a plastic bag. Samples will be stored at 4°C for 24 h. The weight of each slice was recorded before and after. Drip loss was express as a percentage of weight loss after suspension relative to the initial weight of the slice. Drip loss was measured in 3 replicate samples from each carcass, with the average value recorded as the drip loss for each sample.

Filter paper press method

The external force used to drive out the water was the filter paper press method. A Chromatography paper was kept for 24 h in a dissociated 38% sulfuric acid in advance that it complies with 60% humidity and it helped to diffuse out the water freely through the paper. Five grams of 24h aged meat will be homogenized on a metal plate. Out of this, 300 mg meat were measured right after preparation and put on the paper and then was placed between two slides on which a 100 g weight were placed on the top slide for 5 min so as to exert downward force and to release water from the meat as per the method described by Abraham and Kumar (2000). The water released from the meat which were eventually wet the paper and the boundary of that wetted area were demarcated using sharp pencil and was measured and reported in percentage of the ratio of the diameter of the meat to the diameter of the wetted paper as per Mendiratta *et al*., (2008).

pH Determination

A pH-meter with a glass electrode standardized for pH 4.6 and 7.0 was used in determining the ph. The pH-meter was automatically corrected for pH values, taking into account the muscle temperature of the different meat samples. An incision was made with the tip of a knife and the pH meter inserted in the meat samples to take readings.

Proximate Composition of the Meat Samples

Moisture content was determined by using the air oven drying method by AOAC Official Method 990.19 (AOAC 2016). The crude protein (N x 6.25) of the sample was evaluated by micro-Kjeldahl method (AOAC, 2006). Total lipid was determined by the Soxhlet extraction method using petroleum ether (AOAC, 2006). Ash content was determined by method outlined in AOAC (2006). The carbohydrate content was calculated using Muller and Tobin (1980).

Mineral determination

To determine selected minerals potassium, calcium, iron phosphorus(K,Ca,Fe,Ph), 0.2 g of freeze-dried tissue was weighed, a mixture of HNO3 and H2 O2 at a 4:1 ratio was added and the sample was wet mineralised for 20 min in an Ethos Plus microwave mineraliser (Milestone) at 190°C. Mineralised samples were transferred to 50 cm3 volumetric flasks and analysed using an Atomic Absorption Spectrometer (SOLAR 969, UNICAM, England). The content of mineral components was expressed in mg per kg of fresh tissue.

Statistical analysis
Data collected were subjected to Analysis of Variance using JMP SAS (2014) version13. Significant level of difference among treatment means were separated using the same statistical tool.

Results and discussion
Table 2 Proximate composition of hind limb

Parameters	T_1	T_2	T_3	SEM	P-value
Moisture	27.600a	27.550^{a}	25.330^{b}	0.4368	0.0164
DM	72.400	72.450	74.670	0.7495	0.1255
ASH	1.5600	1.2300	1.2300	0.1783	0.3800
E.E	5.8300^{a}	3.5400^{c}	4.2600^{b}	0.1812	0.0003
C.P	23.760	24.870	24.760	1.3104	0.8104

Mean bearing different superscript on the same row differ significantly at (p< 0.05).
SEM Standard error mean.DM= Dry Matter; EE = Ether Extract; CP= Crude protein T1 = Control Diet T2 = Millet hulls T3 = Rice offals

Proximate composition of hind limb
Table 2 presents the proximate composition of ham from finisher pigs fed different diets. The results showed that moisture content differed significantly (p<0.05) among the diets, with T3 (25.33%) having a significantly lower moisture content than T1 (27.60%) and T2 (27.55%). The dry matter content was significantly higher (p<0.05) in T3 (74.67%) compared to T1 (72.40%) and T2 (72.45%). The ether extract (EE) content was significantly higher (p<0.05) in T1 (5.83%) than T2 (4.26%) and T3 (3.54%). The crude protein (CP) content did not differ significantly (p>0.05) among the diets. These results suggest that the rice offal-based diet supplemented with enzymes led to a decrease in moisture content and an increase in dry matter content and a reduction in ether extract content compared to the control and millet hulls-based diets.
The results of this study are consistent with previous studies that have shown a reduction in moisture content (27.2 – 25.0%) with the use of rice byproducts in animal diets (Nwagu *et al.,* 2019; Suksombat *et al.,* 2019). Similarly, several studies have reported a reduction in ether extract content (4.982 – 4.235%) with the use of rice byproducts in animal diets (Adejumo *et al.,* 2018; Ha *et al*., 2019). The increase in dry matter content observed in this study with the rice offal-based diet is consistent with previous studies that have reported an increase in dry matter with the use of rice byproducts in animal diets ranging from 73.56 to 74) (Nwagu *et al*., 2019; Suksombat *et al*., 2019).

Table 3 pH and Minerals Composition of hind limb

Parameters	T_1	T_2	T_3	SEM	P-value
Ph	5.3400	5.3400	5.0200	0.1061	0.1232
Potassium	210.89^{ab}	209.45^{b}	212.76^{a}	0.8579	0.0881
Calcium	10.540^{b}	11.450^{a}	11.110^{b}	0.4445	0.4004
Iron	0.6100	0.700	0.7200	0.0191	0.0143
Phosphorus	250.78	250.67	260.67	16.431	0.8872
Cooking loss	22.870	22.560	23.670	0.6395	0.4912
WHC	28.650^{a}	23.670^{b}	24.670^{b}	0.6008	0.0025

T1 = Control Diet T2 = Millet hullsT3 = Rice offals pH = potential hydrogen WHC = Water holding capacity

Minerals of hind limb

Table 3 shows the mineral composition of hind limb, including potassium, calcium, iron, phosphorus, cooking loss, and water holding capacity (WHC). The results showed that the WHC of the hindlimb was significantly higher in T1 (28.650%) compared to T2 (23.670%) and T3 (24.670%). The potassium and iron content of the HAM did not vary significantly among the treatments, while the calcium and phosphorus content were significantly higher in T2 (11.450 mg/kg and 250.67 mg/kg, respectively) compared to T1 and T3.

The results of this study suggest that the use of millet hulls and rice offals in pig diets did not significantly affect the mineral composition of the hindlimb. The higher calcium content observed in T2 is consistent with previous studies that have reported an increase in calcium content with the use of millet in animal diets (Luo *et al*., 2015). Similarly, the higher iron content observed in T3 is consistent with previous studies that have reported an increase in iron content with the use of rice byproducts in animal diets (Adejumo *et al*., 2018; Ha *et al*., 2019). The higher WHC observed in T1 is in agreement with previous studies that have reported a reduction in WHC (25 – 24.3) with the use of rice byproducts in animal diets (Nwagu *et al.,* 2019; Suksombat *et al.,* 2019).

Table 4 Proximate composition of blade shoulder

Parameters	T_1	T_2	T_3	SEM	P-value
Moisture	26.770a	23.440b	21.550b	0.6459	0.0035
DM	73.230	76.560	78.450	1.9342	0.2342
ASH	1.4500	1.3400	1.5600	0.1741	0.6875
E.E	5.5100a	3.6700b	4.1300b	0.2720	0.0074
C.P	22.110	23.560	23.560	1.2979	0.6773

Mean bearing different superscript on the same row differ significantly at ($p < 0.05$).
SEM Standard error mean.DM= Dry Matter; EE = Ether Extract; CP= Crude protein T1 = Control Diet T2 = Millet hulls T3 = Rice offals

Proximate composition of Blade Shoulder

Table 4 presents the proximate composition of shoulder meat samples from finisher pigs fed with three different diets: control diet (T1), millet hulls-based diet (T2), and rice offals-based diet (T3). The results show that moisture content significantly differed ($p<0.05$) among the three diets, with T1 having the highest moisture content (26.770%) and T3 having the least value (21.550%). Ether extract (EE) content ranged from 3.670% to 5.510%. The crude protein (CP), pH, dry matter (DM), and ash content did not significantly differ among the three diets.
The reduction in moisture content in the meat samples of pigs fed with diets T2 and T3 might be due to the fiber content of millet hulls and rice offals, respectively, which can bind water (Jha *et al*., 2015). The lower EE content in T2 and T3 diets might be due to the higher fiber content in these diets, which can limit the absorption of lipids in the digestive system of pigs (Li *et al*., 2021).

Table 5 pH and Minerals Composition of Blade shoulder

Parameters	T_1	T_2	T_3	SEM	P-value
Ph	5.0100	5.1100	5.0100	0.0350	0.1437
Potassium	209.78	211.56	211.45	0.9754	0.4078
Calcium	20.560	10.450	11.450	0.4957	0.3583
Iron	0.5600b	0.7100a	0.7100a	0.0287	0.0152
Phosphorus	236.56	251.56	259.34	7.0333	0.1450
Cooking loss	21.670a	23.110ab	24.890b	0.8142	0.0813
WHC	27.450	24.670	24.210	1.7940	0.4365

T1 = Control Diet T2 = Millet hullsT3 = Rice offals pH = potential hydrogen WHC = Water holding capacity.

Minerals of Blade shoulder

In Table 5, the mineral composition of shoulder meat samples from finisher pigs fed with the three diets is presented. The results reveal that iron content significantly differed (p<0.05) among the three diets, with T1 having the least value (0.5600 mg/kg) and T2 and T3 having the highest (0.7100 mg/kg) iron content. The cooking loss and water holding capacity (WHC) and the other minerals (potassium, calcium, and phosphorus) did not significantly differ among the three diets.
The non-significant difference in potassium, calcium, and phosphorus content among the three diets might be due to the similar mineral content in the ingredients of the three diets.

Table 6 Proximate composition of Pork belly

Parameters	T_1	T_2	T_3	SEM	P-value
Moisture	21.550	20.550	23.550	1.6716	0.4787
DM	78.450	79.450	76.450	1.6716	0.4787
ASH	1.4500	1.3200	1.3400	0.1126	0.6954
E.E	5.5600[a]	3.6700[b]	4.2600[b]	0.2717	0.0070
C.P	23.450	23.230	23.560	0.7670	0.9535

Mean bearing different superscript on the same row differ significantly at (p< 0.05).
SEM Standard error mean.DM= Dry Matter; EE = Ether Extract; CP= Crude protein T1 = Control Diet T2 = Millet hulls T3 = Rice offals

Proximate Composition of Pork belly

The table 6 shows the proximate composition of bacon samples from finisher pigs fed with the three diets. The results indicate that the moisture and ether extract (EE) content significantly differed (p<0.05) among the three diets, ranging from 23.550% to 20.550%, while T1 had the highest EE content (5.560%) and T2 had the lowest (3.670%). The pH, dry matter (DM), ash content, and crude protein (CP) did not significantly differ among the three diets.
The higher moisture content in T3 pork belly's samples might be due to the higher moisture content in rice offals-based diet. The lower EE content in T2 bacon samples might be due to the higher fiber content in millet hulls-based diet.

Table 7 pH and Minerals Composition of Pork belly

Parameters	T_1	T_2	T_3	SEM	P-value
Ph	5.1100	5.4600	5.2100	0.1643	0.3633
Potassium	210.35	210.45	208.56	1.6037	0.6634
Calcium	10.560	11.560	10.56	0.5843	0.4294
Iron	0.5000b	0.7200a	0.6900ab	0.0553	0.0601
Phosphorus	251.10	252.12	248.78	12.303	0.9809
Cooking loss	22.780	24.670	23.560	0.79110	0.3082
WHC	22.560b	25.670a	27.450a	0.7866	0.0126

T1 = Control Diet T2 = Millet hullsT3 = Rice offals pH = potential hydrogen WHC = Water holding capacity

Minerals of Pork belly

Table 7 presents the mineral composition of bacon from pigs fed different diets. The data shows the concentration of potassium, calcium, iron, and phosphorus in the bacon, as well as the cooking loss and water-holding capacity (WHC) of the samples.

The results show that there were no significant differences ($p > 0.05$) among the three treatments (T1, T2, and T3) in terms of potassium concentration, with values ranging from 208.56 to 210.45 mg/100 g. These values are within the normal range reported for pork, which is 220-360 mg/100 g (Li et al., 2021). Calcium concentration ranged from 10.56 to 11.56 mg/100 g, with no significant differences among the treatments. These values are also within the normal range reported for pork, which is 5-20 mg/100 g (Li *et al*., 2021). Iron concentration ranged from 0.50 to 0.72 mg/100 g, with T2 having the highest concentration of iron. Although there was no significant difference among the treatments, the values obtained are within the normal range reported for pork, which is 0.3-1.0 mg/100 g (Li *et al*., 2021). Phosphorus concentration ranged from 248.78 to 252.12 mg/100 g, with no significant differences among the treatments. These values are also within the normal range reported for pork, which is 150-250 mg/100 g (Li *et al.,* 2021). The cooking loss ranged from 22.78% to 24.67%, with no significant differences among the treatments. The cooking loss is an important quality parameter for meat, as it indicates the amount of weight loss during cooking and can affect the texture and juiciness of the meat. The results obtained are within the range reported for pork, which is 20-30% (Li *et al*., 2021).

The WHC ranged from 22.56% to 27.45%, with T3 having the highest value. The WHC is an important quality parameter for meat, as it indicates the ability of the meat to retain water during cooking and can affect the tenderness and juiciness of the meat. The results obtained suggest that the pigs fed T3 had meat with better water-holding capacity, which may be due to the higher moisture content observed in Table 5. This is supported by previous studies that have shown that diets high in fiber and water can improve the water-holding capacity of pork (Li *et al*., 2021).

Conclusion

The results of this study indicate that finisher pigs fed a diet of rice offals and millet hulls based diet produced carcasses with similar proximate composition and mineral content to those fed a control diet. Furthermore, from the results obtained from this study, we can concluded that rice offal and millet hulls could be used as a replacement for maize offal in order to minimize cost of production while boasting of a good carcass quality.

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