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EFFECTS OF GRADED LEVELS OF CORN AND COB MEAL ON CARCASS PARAMETERS, ORGAN WEIGHT, VILLI MORPHOMETRIC, AND SENSORY PROPERTIES OF TOPIGS NORSVIN TN70 WEANED PIGS

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ABSTRACT

Thirty-two (32) TN70 (Topigs Norsvin) weaned pigs, aged 7 weeks, having an average weight of 10.5±0.5 kg were used to evaluate the effect of corn and cob meal (CCM) on the carcass parameters, organ weight, villi morphometric, and organoleptic properties of the pigs. CCM was produced by grinding the grain and the cob together. The pigs were acclimatized for seven days before they were randomly allotted to four (4) dietary treatments with eight (8) pigs per replicate in a completely randomized design. The experiment lasted for seven weeks. The feed had 0%, 10%, 20%, and 30% corn and cob meal (CCM) in the diets tagged as D1, D2, D3, and D4 respectively. All the data were analyzed using SPSS version 16 and the means were compared using one-way analysis of variance (ANOVA). Except for the eviscerated weight, back fat, and loin, all the carcass parameters were significantly influenced (P<0.05). The weight of the visceral organs was significantly influenced (P<0.05) except for the weight of the lungs. All the villi morphometric parameters differed significantly (P<0.05) except the crypt width. CCM influenced (P<0.05) the colour, tenderness, juiciness, and overall acceptability of the meat. The use of 30% CCM stimulated pancreas hypertrophy, increased carcass weight, belly, ham, picnic shoulder, villi height, muscle thickness, and improved organoleptic properties.

Keywords: Whole maize, unshelled maize, dietary fibre, pig, maize cob

INTRODUCTION

Globally, pig production amidst other livestock production cannot be underrated **(Maes *et al*., 2020)**. There is a shift from ruminant animal production to that of monogastric animals **(Bai *et al*., 2018)**, especially pigs, due to increasing demand for pork, fast growth, higher returns, and high feed efficiency **(Ironkwe and Amefule, 2008; Adetunji, 2012)**. Pigs have also been known for their unique characteristics of converting feed and food waste to meat **(Ironkwe and Amefule, 2008)**. Beyond the production of pork, pig production is crucial in small-scale farming **(Ogunniyi and Omoteso, 2011)**.
One of the main obstacles to pig production is the cost of feed and sustainable alternatives to conventional feedstuff in quality and availability **(Gaillard *et al*., 2020)**. Feeding costs sum up to about 60 to 80% of the entire cost of producing pigs, making it a significant consideration **(Aminu and Akhigbe-Ahonkhai, 2017)**. Other feed supplies must be investigated in order to address this issue and boost production because the staple foods for humans are the same grains used for animal feed. The feeding of agro-industrial by-products (AIBPs) and residues of crops has been considered **(Georganas *et al*., 2023)**, as these are not consumed by man and can be converted by pigs into desirable meat. This has inspired several studies about the utilization of unorthodox feedstuffs that are of low cost and readily available.
Maize (*Zea mays*), a globally grown grain because of its high productivity for food, feed, and chemical purposes **(Revilla *et al*., 2022)**, yields cobs that can function as a feed substituent **(Kanengoni *et al*., 2004)**. Several attempts have been channeled to the utilization of maize cobs in the production of animal feed due to the intense human demand for grain **(Bozovic *et al*., 2004)**. Maize cobs have been recognized as a viable and low-cost feedstuff as well as a renewable energy source **(Jansen, 2012)** that can be utilized as a substitute for fibre and energy sources in animal feed **(Blandino *et al*., 2016)**. Because of the high levels of fibre in it, maize cob has potential agricultural uses **(Soliman, 2019)**.
Corn and cob meal (CCM) is a product of milling unshelled maize (whole corn grain and cobs) and can be fed fresh, ensiled, or dried. It is of a lower cost when compared with maize grain and on the other hand high in starch and can be used as an energy feed for animals. Because of the presence of cobs in it, CCM has more fibre **(Meyer, 2015)** than grain, thus it can also serve as a fibre source alongside other nutrients **(Njideka *et al*., 2020)**. According to **Millet *et al*. (2005)**, CCM may be a useful local ingredient that may be added at a reasonable cost. This raises the question of whether or not this low-cost feedstuff can be used in the diet of weaned pigs without affecting output and quality while the cost of production is reduced. This study aims to evaluate the effect of CCM on the carcass parameters, organ weight, villi morphometric, and sensory properties of weaned TN 70 pigs.

MATERIAL AND METHODS

Experimental site

The experiment was conducted at Ladoke Akintola University of Technology Teaching and Research Farm's piggery unit, which is located at latitude 18°15'N of the equator and longitude 4°5'E of the Greenwich meridian **(Ojediran *et al*., 2020)**.

Test ingredient and experimental diets

Well-preserved unshelled maize was obtained from the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, a reputable and trusted agricultural firm. The whole maize was ground using a hammer mill with a 2 mm screen size. The meal was mixed with additional feed ingredients.

Table 1 Gross composition of feeding diet

Ingredients	D1 (%)	D2 (%)	D3 (%)	D4 (%)
Maize	10.00	0.00	0.00	0.00
Corn and cob meal	0.00	10.00	20.00	30.00
Soybean meal	10.00	10.00	10.00	12.00
Full fat cashew	7.00	7.00	7.00	4.00
Palm kernel cake	55.00	55.00	55.00	51.00
Wheat offal	15.00	15.00	5.00	0.00
Fixed ingredients	3.00	3.00	3.00	3.00
Total	100	100	100	100
Calculated nutrients				
Metabolizable energy (kcal/kg)	2722.92	2750.81	2775.44	2746.75
Crude protein	19.85	19.67	18.82	18.20
Ether extract	7.34	7.83	7.27	6.05
Crude fibre	8.64	11.02	12.95	14.80

Fixed ingredients: bone meal = 1.50%, limestone = 1.00%, vitamin premix = 0.25%, salt = 0.25%

Thereafter, four experimental diets were formulated with crude protein between 18–19%, metabolizable energy 2700-2800 ME/Kcal/kg as shown in Table 1. CCM was incorporated in the proportion of 10%, 20%, and 30% in Diet 2 (D2), Diet 3 (D3), and Diet 4 (D4) respectively, while Diet 1 (D1) had 10% maize as the control diet.

Experiment pigs and management

Thirty-two (32) TN70 (Topigs Norsvin) weaned pigs, 7 weeks old with an average weight of 10.5 ± 0.5 kg were used for this study. The pigs were housed individually in a concrete open-sided pig pen that was properly ventilated (1.5m x 1.5m), acclimatized for one week before the administration of ivermectin (0.5 mL/10 kg) and tylosine (1 mL/10 kg), intravenously and intramuscularly, respectively, handled and managed in accordance with the NIH Guide for the Care and Use of Laboratory Animals (NIH publication No 86-23, amended 1985 and 1991) and the United Kingdom's ethical criteria for animal experimentation (Animals Scientific Procedures Act 1986) **(Ojediran *et al*., 2020)**. The weaned pigs were randomly allotted to four (4) dietary groups in a completely randomized design, with eight (8) pigs per replicate. The animals had access to feed and water *ad libitum*. The experiment was conducted for 49 days.

Data Collection

At the end of the experiment, three pigs (3) per replicate were slaughtered at the piggery unit slaughter slab of the Department of Animal Nutrition and Biotechnology, LAUTECH, following the proper hygienic practises. Prior to slaughtering, the pigs were fasted for eight hours, mechanically immobilized as described by **Riaz *et al*. (2021)** before their jugular vein was severed and allowed to bleed properly before being eviscerated. Following that, the carcasses were cut into primal cuts and the visceral organs were also separated following the method described by **Bridi & Silva (2009)**. The visceral organs were weighed on a kerro electronic compact scale, model BL30001E, the carcasses were weighed using a crane™ mini scale (model: MNCS-M), and the back fat was measured as described by **Peloso *et al*. (2010).**

Approximately 5 cm in length of the jejunum of each pig was obtained between the distal portion of the duodenal loop and the ileocecal junction. The tissues were cut longitudinally, washed in saline solution, and fixed in 10% buffered formalin. Each fragment was processed for paraffin embedding, sectioned, and stained following the hematoxylin and eosin method according to the procedures described by Regiane *et al*. (2015). The tissues were thereafter examined with a Nikon phase contrast microscope coupled with a Microcomp integrated digital imaging analysis system (Nikon Eclipse 80i, Nikon Co., Tokyo, Japan). Villus length, width, and Crypt depth were measured as described by **Giannenas *et al*. (2010)**.

Pre-labeled ham samples (200g) were taken from all the treatment groups, cut into pieces, cooked in hot water at 100℃ for 15 minutes using a pressure pot on a kitchen gas cooker, and allowed to cool before being served to ten trained panelists as coded samples to evaluate the organoleptic qualities (colour, flavour, tenderness, juiciness, and general acceptability) of the meat as outlined by **Ojediran *et al*. (2019)**. The description was evaluated on a 9-point hedonic scale, with 1 indicating dislike strongly and 9 indicating like excessively according to **Válková (2012)**. Each scorer was provided with a bottle of table water and pieces of bread to serve as flavour neutralizers between samples.

Experimental design and statistical analysis

The design of the experiment was Completely Randomized Design (CRD). Statistical package for social science, SPSS, version 16 was used for the analysis. All the data obtained from the experiment were subjected to statistical analysis using one-way analysis. The treatment means were presented with group standard errors and the statistics were compared using the Duncans Multiple Range (DMR) test procedure of test with a probability of 5% (P level = 0.05). The statistical model used was:

$Y_{ij} = \mu + CCM_i + e_{ij}$

Y_{ij} = Individual observation

μ = population mean

CCM_i = effect of i^{th} corn and cob meal diets

e_{ij} = random error

RESULTS

Table 2 shows the carcass parameters of weaned pigs fed varying levels of CCM expressed as a percentage of the live weight. All the parameters were significantly different (P<0.05) except the back fat and loin. The pigs fed D1, D2, and D4 had similar carcass weight proportions while the carcass weight of the pigs fed D3 was 53.08%. The weight of the total visceral organs of the pigs fed D2 (20.47%) and D3 (22.13%) were significantly different from each other (P<0.05) while those fed D1 (21.08%) and D4 (21.48%) were comparable. The pigs fed diet D2 had the highest jowl weight (2.80%) followed by those fed D1 (2.28%), D3 (2.23%) and D4 (1.53%) being the least. The pigs fed D3 had the highest head weight (11.28%) followed by those fed D4 (10.11%), D1 (9.46%), and D2 (9.27%). The weight of the buston butt of the pigs fed diet D1 (8.49%), D2 (9.03%), D3 (10.57%) and D4 (9.11%) were significantly different (P<0.05). The pigs fed D2 had the highest weight of spare rib as expressed as a percentage of live weight (7.79%), followed by D1 (7.38%), D4 (6.10%), and D3 (5.63%). The weight of the belly of the pigs increased in those fed different inclusion levels of CCM (P<0.05). The weight of the ham of the pigs was significantly different (P<0.05). Pigs fed D4 had the highest weight (14.30%) while pigs fed D2 had the least (13.23%). The weight of the trotter decreased with the increase in the inclusion level of CCM. The pigs fed D4 had the highest value for the weight of picnic shoulder (7.54%) followed by D1 (7.11%), D2 (6.60%), and D3 (6.22%).

Table 2 Carcass parameters of weaned pigs fed varying levels of CCM expressed as a percentage of live weight

Parameters (%)	D1	D2	D3	D4	SEM	P value
Bled weight	92.91^b	91.65^c	94.18^a	93.17^b	0.97	0.01
Eviscerated weight	70.78	69.40	70.39	70.50	0.24	0.18
Carcass weight	55.60^a	55.00^a	53.08^b	55.62^a	0.33	0.00
Total visceral organs	21.08^{ab}	20.47^b	22.13^a	21.48^{ab}	0.23	0.05
Back fat thickness (cm)	0.35	0.30	0.30	0.33	0.01	0.14
Jowl	2.28^a	2.80^a	2.23^a	1.53^b	0.14	0.00
Head	9.46^c	9.27^c	11.28^a	10.11^b	0.21	0.00
Buston butt	8.49^b	9.03^b	10.57^a	9.11^b	0.26	0.01
Loin	14.69	12.73	13.27	13.00	0.39	0.32
Spare rib	7.38^a	7.79^a	5.63^b	6.10^b	0.27	0.00
Belly	5.29^b	5.71^a	5.61^{ab}	5.87^a	0.07	0.02
Ham	13.52^a	13.23^b	13.38^{ab}	14.30^a	0.17	0.03
Trotter	1.89^a	1.94^a	1.89^a	1.69^b	0.04	0.04
Picnic shoulder	7.11^b	6.60^{bc}	6.22^c	7.54^a	0.17	0.02

a–c means within the row lacking common superscript differ (p<0.05); SEM – standard error of means; cm – Centimeter

Table 3 shows the organ weight expressed as a percentage of the live weight of weaned pigs fed varying levels of CCM. The percentage weight of the lung does not differ significantly (P>0.05) while the weight of other visceral organs of the animals was significantly different (P<0.05). The total weight of the visceral organs of the animals fed diets D2 and D3 were significantly different (P<0.05) while those fed D1 and D4 were comparable. The liver's weight of all of the animals was significantly influenced (P<0.05) by the dietary treatment with D2 being the highest (2.73%) while D4 being the least (2.22%) and D1 and D3 recorded at 2.65% and 2.29% respectively. The weight of the kidney showed that animals fed D2 had the highest kidney weight (0.52 %) while animals fed D3 had the least (0.45%). Pigs fed D3 had the highest heart weight (0.45 %) while those fed other diets were lower, the weight of the hearts of the animals fed D3 was significantly different (P<0.05) from D1, D2, and D4. Pigs fed D3 had the highest percentage weight of spleen (P<0.05), 0.14%, while others were lower. The weight of the spleen of the pigs fed D2, D3, and D4 were significantly different (P<0.05) while the weight of the spleen of pigs fed D1 was comparable. The pancreas' weight of the pigs fed D4 was the highest and was significantly different from the other (P<0.05) while the pancreas' weights of the pigs fed D1, D2, and D3 were similar. Pigs fed D1 had the whole stomach with the highest percentage live weight (2.12 %), and it was significantly different (P<0.05) from the whole stomach weight of the pigs fed D3. The whole stomach's weight of the animal fed D2 and D4 were comparable (P<0.05). The weight of the empty stomach of all the animals was significantly influenced (P<0.05). Pigs fed D1 and D2 had the same empty stomach weight and they recorded the highest value (1.12 %) while the animals fed D3 had the least (0.83%).

Table 3 Organ weight expressed as a percentage of the live weight of weaned pigs fed varying levels of CCM

Parameters (%)	D1	D2	D3	D4	SEM	P value
Total visceral organ	21.08^{ab}	20.47^{b}	22.13^{a}	21.48^{ab}	0.23	0.04
Liver	2.65^{a}	2.73^{a}	2.29^{b}	2.22^{b}	0.06	0.00
Kidney	0.46^{b}	0.52^{a}	0.45^{b}	0.50^{a}	0.01	0.00
Heart	0.41^{b}	0.40^{b}	0.45^{a}	0.39^{b}	0.01	0.00
Spleen	0.12^{bc}	0.12^{c}	0.14^{a}	0.13^{b}	0.02	0.00
Pancreas	0.21^{b}	0.23^{b}	0.21^{b}	0.30^{a}	0.01	0.00
Whole stomach	2.12^{a}	1.52^{bc}	1.28^{c}	1.89^{ab}	0.10	0.00
Empty stomach	1.12^{a}	1.12^{a}	0.83^{c}	1.04^{b}	0.03	0.00
Lung	0.88	0.94	0.85	0.86	0.02	0.16

a–c means within the row lacking common superscript differ (p<0.05); SEM – standard error of means

Table 4 shows the villi morphometric of weaned pigs fed varying levels of CCM. The villi height (VH), villi width (VW), cryptal depth (CD), and muscle thickness (MW) were significant (P<0.05) while the cryptal width (CW) was not significant (P>0.05). The pigs fed D4 had the highest villi height (3006.51) and the same pattern was recorded for muscle thickness with D4 having 392.02 and D1 with 279.78. The pigs fed D2 had the highest villi width (218.73) while D4 had the least (208.96). The cryptal depth of D1, D2, D3, and D4 respectively are 435.77, 352.79, 352.86, and 352.93.

Table 4 Villi morphometric of weaner pigs fed varying levels of CCM

Parameters (µm)	D1	D2	D3	D4	SEM	P value
Villi height	2448.98^{c}	2273.91^{d}	2640.21^{b}	3006.51^{a}	83.68	0.00
Villi width	210.11^{b}	218.73^{a}	213.84^{ab}	208.96^{b}	1.55	0.04
Crypt depth	435.77^{a}	352.79^{b}	352.86^{b}	352.93^{b}	11.32	0.00
Crypt width	213.10	210.13	212.73	215.34	1.84	0.85
Muscle thickness	279.78^{c}	273.18^{c}	301.10^{b}	329.02^{a}	6.94	0.00

a–d means within the row lacking common superscript differ (p<0.05); SEM – standard error of means

Table 5 shows the organoleptic properties of weaner pigs fed varying levels of CCM. The flavour and texture were not significantly affected (P>0.05) while colour, tenderness, juiciness, and overall acceptability were significantly affected (P<0.05). The meat's tenderness and juiciness followed the same pattern across the dietary levels with D1 having the highest values and D3 with the least. Pigs fed D3 had the highest value for colour (6.70) while D1 had the least (4.90) and D2 and D4 had 6.40 and 6.50 respectively. The overall acceptability for the dietary levels were 7.30, 7.40, 6.50, and 7.00 respectively.

Table 5 Organoleptic properties of weaned pigs fed varying levels of CCM

Parameters	D1	D2	D3	D4	SEM	P value
Colour	4.90^{b}	6.40^{a}	6.70^{a}	6.50^{a}	0.22	0.01
Flavour	3.50	4.70	3.40	4.30	0.29	0.34
Tenderness	5.10^{a}	4.70^{a}	2.80^{b}	4.40^{a}	0.27	0.01
Juiciness	5.90^{a}	5.10^{a}	4.20^{b}	5.40^{a}	0.28	0.04
Texture	5.40	5.10	3.40	4.70	0.34	0.17
Overall acceptability	7.30^{a}	7.40^{a}	6.50^{b}	7.00^{ab}	0.26	0.02

a–b means within the row lacking common superscript differ (p<0.05); SEM – standard error of means

DISCUSSION

As the level of inclusion increased, the fibre content of the diets also increased while the crude protein content reduced. The impact of dietary fibre on the pig carcass parameters has been a subject of study for a very long time. In previous studies, high dietary fibre has been proven to reduce the carcass characteristics of pigs **(Li *et al*., 2021)**. However, studies by **Stewart *et al*. (2012)** reported that high dietary fibre improved the carcass parameters of pigs, specifically in terms of weight. The decrease in the carcass weight, jowl, spare rib, and trotter agrees with the report of **Li *et al*. (2021)**. Because high dietary fiber diets have a negative influence on the growth of pigs **(Agyekum and Nyachoti, 2017)**, the reduction in the parameters as observed by **Li *et al*. (2021)** was linked to the direct relationship between carcass parameters and body weight gain. However, **Xie *et al*. (2023)** also affirm the direct relationship between the carcass characteristics and the growth performance of pigs. Thus, the reduction in the carcass weight of pigs fed D2 and D3, the weight of jowl of pigs fed D3 and D4, and the weight of the spare rib of pigs fed D3 and D4, can be attributed to this reason. However, certain parameters such as the weight of the head, buston butt, ham, and picnic shoulder increased with the increase in the inclusion level of CCM and this could be due to the influence of factors such as genetics, handling techniques and management practices **(Choi *et al*. 2019)**.

Studies on the impact of increasing dietary fibre on the overall weight of visceral organs have produced mixed findings. The observation in this study, as regards the weight of the visceral organ, agrees with the report of **Agyekum and Nyachoti (2017)**, a systematic review of the nutritional consequences of a high-fibre diet on pigs, and this can be attributed to the filling nature of fibre on the gastrointestinal tract of the pigs. The liver is a site for metabolic reactions in response to dietary changes because it receives blood through the portal vein **(Kieffer *et al*., 2016)**. The reduction in the liver weight of the pigs as observed agrees with the report of **Zou *et al.* (2019)** and **Zhang *et al.* (2019a)**. **Zou *et al.* (2019)** found that feeding a diet of a high level of fibre to finishing pigs for 35 days reduced liver weight and improved liver function compared to pigs fed a low-fibre diet. The study of **Zhang *et al.* (2019a)** using growing pigs found that feeding a diet high in fibre and low in protein for 10 weeks improved liver function and reduced liver weight compared to a control diet. However, the increase in the amount of fibre in the feed may have an impact on liver metabolism by changing bile acid pools, which helps the absorption of dietary fat and fat-soluble vitamins as well as signaling molecules **(Makishima *et al*., 1999)**. As a result, this may be the reason for the reduction in the weight of the liver.

The weight of the kidney can be used as an indicator of toxicity in feeding trials **(Khan *et al*., 2013)**. The fibre content of a feed may reduce nitrogen burden and systemic inflammation and it may improve the kidney's function by increasing the glomerular filtration rate, a measure of kidney function **(Shen *et al*., 2014)**. Fibre consumption has also been researched as a dietary component that may improve kidney function through a variety of processes **(Camerotto *et al*., 2019)**. The increased fibre composition of the diets with varying levels of CCM could be the reason for the increased kidney weight of the pigs particularly those fed D2 and D4 compared to the size of the kidney of the pigs fed D1.

Soluble fibre can reduce total and LDL cholesterol in the blood (Soliman, 2019). Whether the weight of the heart and its biological significance is influenced by high dietary fibre has not been determined but it is assumed that prolonged intake of diets containing high levels of fibre by pigs may lead to hypertrophy and hence increase the weight of segments of the gastrointestinal tract and the heart **(Ma *et al*., 2002)**. The effect of this study on the heart of pigs fed varying level of CCM agrees with the report of the study carried out by **Ma *et al*. (2002)**, where the effect of high dietary fibre source (wheat bran) on the organ weight of growing pigs was studied.

The spleen, the largest lymphoid organ, has specific functions of blood filtration and serves as the main site for immune cell growth and development. It participates in the phagocytosis of aging erythrocytes and haematopoiesis (Wu *et al*., 2020). The inclusion of high fibre as a result of CCM inclusion in the pig's diet increased the weight of the spleen of the pigs fed varying levels of CCM, and this report agrees with the conclusion of **Asmus *et al.* (2014)**, and it could be as a result of factors such as overall health, blood volume, and the presence of any underlying medical conditions.

The pancreas is also one of the most important organ in the digestive process because it produces and secretes the enzymes required for the digestion of chyme and the avoidance of pH-related cell damage **(Patricia and Dhahmoon, 2022)**. The study of **Shen *et al.* (2014)** using growing pigs found that feeding a high-fibre diet for 5 weeks improved pancreatic function by increasing the secretion of pancreatic enzymes. High dietary fibre can increase pancreatic enzymatic activity, increasing the digestion of nutrients **(Hetland *et al*., 2003; Mateos *et al*., 2012)**.

The significance of CCM could be due to physiological activities stimulated in the pancreas for the release of the pancreatic juice into the small intestine needed for the breakdown of the nutrient composition of the feed. The increase in the crude fibre composition of D4 (18.20% CF) compared with D1, D2, and D3 (8.64% CF, 11.02% CF and 12.95% CF respectively) could be the cause of the increase in the weight of the pancreas as recorded in the animals fed D4.
The stomach weight and size (empty and whole) are mainly influenced by the amount of feed consumed by the animal. Because the animals are fed *ad libitum*, they tend to ingest more, increasing their stomach size. Contrarily, research has shown that dietary fibre may change both the rate of stomach emptying and gastric acidity, resulting in fewer gastroesophageal refluxes and a reducing the capability for harm **(Morozov *et al*., 2018)**.
Non-digestible carbohydrates, crude fibre, have been linked with better health outcomes, particularly in terms of gut health **(Reynolds *et al*., 2020)** and their presence in the diet can delay the emptying rate of the gastrointestinal tract (GIT), impact the diversity of the bacterias present within the GIT, and fermentation **(Desai *et al*., 2016)**. Villi are important structures in the small intestine which is involved mainly in nutrient absorption **(Fuller, 2004)**. The increase in the villi height, width, and muscle thickness may be associated with the stimulation of reverse peristaltic movement because of the presence of fibre in the diet **(Ho *et al*., 2012)**. The thick and preserved intestinal muscular thickness of the pigs revealed that there was a direct relationship between the increased dietary crude fibre and the thickness and this increase in the muscular thickness will function to protect the wall from antagonizing organisms, thus supporting the immune system of the pigs or animals.
The depth of the crypt is an indicator of the intestine's health in every animal, and its size may be used to determine the intensity of the renewal activity of the intestinal epithelial cell **(Samanya and Yamauchi, 2002)**. There was a reduction in the crypt depth of the pigs as the inclusion level of CCM in the diet increased and this observation went against the report of **Hunt *et al.* (2021)** where there was a decrease in the crypt depth when crude dietary fibre deficient feed was offered for 21 days to mice. According to **Xu *et al*. (2003)**, "the crypt is often considered to be the villus factory, and a large crypt implies quick turnover of tissue and a high demand for new tissue," the decreased crypt depth in this study could represent an effective tissue turnover and good gut health.
Meat colour is the crucial appearance quality of the meat because the consumer **(Joo *et al*., 2013)** first notices it, and it is used to measure its freshness and wholesomeness. The colour of meat is influenced by several factors which include species, age, muscle type, consumer preference, and majorly by the content of myoglobin (Mb) in the muscle **(Joo *et al*., 2013 and Ojediran *et al*., 2019)**. The myoglobin oxidation rate is the main factor affecting meat colour **(Faustman *et al*., 2010)**. As a result, decreased oxidation will cause the meat's pH to decline, which will result in paler meat **(Kim *et al*., 2011)**. The use of CCM enhanced meat colour in this study.
Several factors such as age, gender, and genotype, as well as pre-slaughter factors such as transportation and handling stress can influence the meat tenderness of pigs fed with high dietary fibre. High dietary fibre has been reported to significantly decrease meat deposition in weaned pigs **(Wang *et al*., 2016)**. The reduction in meat tenderness as observed in this study agrees with the report of **Alakali *et al.* (2010)**. This might be a result of the higher level of dietary insoluble fibre, that can bind to water and decrease the meat's ability to hold water. Although there are few or no data that imply that feeding pigs this diet can reduce the juiciness of the meat, the influence of feeding pigs a high dietary fibre diet on the meat's tenderness may also have an impact on the juiciness of the meat.
Meat's overall acceptability reflects the consumer's preference **(Ojediran *et al*., 2019)**, therefore, the increased dietary fibre as a result of the inclusion of CCM in the diets that have influenced the colour, tenderness, juiciness could have been the factor that influenced the overall acceptability of the meat.

CONCLUSION

Up to a 30% inclusion level of CCM is favorable based on its effect on the carcass parameters, villi morphometric, and meat properties. CCM had no deleterious effect on the visceral organs of the pigs. Up to 30% inclusion level of CCM in weaned diet is recommended. Further experiments can be conducted on the use of exogenous enzymes.

Ethics approval: All procedures employed in this study were sanctioned by the Animal and Research Ethics Committee of the Ladoke Akintola University of Technology with approval number ANB/20/22/147339U.

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REFERENCES

Adetunji, M. (2012). Economic Efficiency of Pig Production in Oyo State, Nigeria: A Stochastic Production Frontier Approach. *American Journal of Experimental Agriculture*, *2*(3), 382–394. https://doi.org/10.9734/ajea/2012/746
Agyekum, A. K., & Nyachoti, C. M. (2017). Nutritional and Metabolic Consequences of Feeding High-Fiber Diets to Swine: A Review. *Engineering*, *3*(5), 716–725. https://doi.org/10.1016/j.eng.2017.03.010
Alakali, J., Irtwange, S., & Mzer, M. (2010). Quality evaluation of beef patties formulated with bambara groundnut (Vigna subterranean L.) seed flour. *Meat Science*, *85*(2), 215–223. https://doi.org/10.1016/j.meatsci.2009.12.027
Aminu, F. O., & Akhigbe-Ahonkhai, C. E. (2017). Profitability and Technical Efficiency of Pig Production in Nigeria: the Case of Ekiti State. *Agricultura Tropica Et Subtropica*, *50*(1), 27–35. https://doi.org/10.1515/ats-2017-0004
Bai, Z., Ma, W., Ma, L., Velthof, G. L., Wei, Z., Havlík, P., Oenema, O., Lee, M. R. F., & Zhang, F. (2018). China's livestock transition: Driving forces, impacts, and consequences. *Science Advances*, *4*(7). https://doi.org/10.1126/sciadv.aar8534
Blandino, M., Fabbri, C., Soldano, M., Ferrero, C., & Reyneri, A. (2016). The use of cobs, a by-product of maize grain, for energy production in anaerobic digestion. *Italian Journal of Agronomy*, *11*(3), 195–198. https://doi.org/10.4081/ija.2016.754
Bozovic, I., Radosavljevic, M., Zilic, S., & Jovanovic, R. (2004). A genetic base of utilisation of maize cob as a valuable naturally renewable raw material. *Genetika*, *36*(3), 245–256. https://doi.org/10.2298/gensr0403245b
Bridi, A. M., & Silva, C. A. (2009). Avaliação da carne suína (1st ed.). Londrina: Midiograf.
Camerotto, C., Cupisti, A., D'Alessandro, C., Muzio, F., & Gallieni, M. (2019). Dietary Fiber and Gut Microbiota in Renal Diets. *Nutrients*, *11*(9), 2149. https://doi.org/10.3390/nu11092149
Choi, J., Kwon, K., Lee, Y., Ko, E., Kim, Y., & Choi, Y. (2019). Characteristics of Pig Carcass and Primal Cuts Measured by the Autofom III Depend on Seasonal Classification. *Food Science of Animal Resources*, *39*(2), 332–344. https://doi.org/10.5851/kosfa.2019.e30
Desai, M. S., Seekatz, A. M., Koropatkin, N. M., Kamada, N., Hickey, C. A., Wolter, M., Pudlo, N. A., Kitamoto, S., Terrapon, N., Muller, A., Young, V. B., Henrissat, B., Wilmes, P., Stappenbeck, T. S., Núñez, G., & Martens, E. C. (2016). A Dietary Fiber-Deprived Gut Microbiota Degrades the Colonic Mucus Barrier and Enhances Pathogen Susceptibility. *Cell*, *167*(5), 1339-1353.e21. https://doi.org/10.1016/j.cell.2016.10.043
Faustman, C., Sun, Q., Mancini, R., & Suman, S. P. (2010). Myoglobin and lipid oxidation interactions: Mechanistic bases and control. *Meat Science*, *86*(1), 86–94. https://doi.org/10.1016/j.meatsci.2010.04.025
Fuller, M. F. (Ed.). (2004). *The encyclopedia of farm animal nutrition*. https://doi.org/10.1079/9780851993690.0000
Gaillard, C., Brossard, L., & Dourmad, J. Y. (2020). Improvement of feed and nutrient efficiency in pig production through precision feeding. *Animal Feed Science and Technology*, *268*, 114611. https://doi.org/10.1016/j.anifeedsci.2020.114611
Georganas, A., Giamouri, E., Pappas, A. C., Zoidis, E., Goliomytis, M., & Simitzis, P. (2023). Utilization of Agro-Industrial By-Products for Sustainable Poultry Production. *Sustainability*, *15*(4), 3679. https://doi.org/10.3390/su15043679
Hetland, H., Svihus, B., & Krogdahl. (2003). Effects of oat hulls and wood shavings on digestion in broilers and layers fed diets based on whole or ground wheat. *British Poultry Science*, *44*(2), 275–282. https://doi.org/10.1080/0007166031000124595
Ho, K. S., Tan, C. Y., Mohd Daud, M. A., & Seow-Choen, F. (2012). Stopping or reducing dietary fiber intake reduces constipation and its associated symptoms. *World journal of gastroenterology*, *18*(33), 4593–4596. https://doi.org/10.3748/wjg.v18.i33.459
Hunt, J. E., Hartmann, B., Schoonjans, K., Holst, J. J., & Kissow, H. (2021). Dietary Fiber Is Essential to Maintain Intestinal Size, L-Cell Secretion, and Intestinal Integrity in Mice. *Frontiers in Endocrinology*, *12*. https://doi.org/10.3389/fendo.2021.640602
Ironkwe, M., & Amefule, K. (2008). Appraisal Of Indigenous Pig Procution And Management Practices In Rivers State, Nigeria. *Journal of Agriculture and Social Research (JASR)*, *8*(1). https://doi.org/10.4314/jasr.v8i1.2878
Jansen, C. (2012). Breeding for cob traits in maize. (Doctoral dissertation). Iowa State University. Retrieved from https://lib.dr.iastate.edu/etd/12982
Joo, S., Kim, G., Hwang, Y., & Ryu, Y. (2013). Control of fresh meat quality through manipulation of muscle fiber characteristics. *Meat Science*, *95*(4), 828–836. https://doi.org/10.1016/j.meatsci.2013.04.044
Kanengoni, A. T., Dzama, K., Chimonyo, M., Kusina, J., & Maswaure, S. M. (2004). Growth performance and carcass traits of Large White, Mukota and Large White × Mukota F1crosses given graded levels of maize cob meal. *Animal Science*, *78*(1), 61–66. https://doi.org/10.1017/s1357729800053844
Khan, K. N. M., Hard, G. C., & Alden, C. L. (2013). Kidney. *Haschek and Rousseaux's Handbook of Toxicologic Pathology*, 1667–1773. https://doi.org/10.1016/b978-0-12-415759-0.00047-9
Kieffer, D. A., Martin, R. J., & Adams, S. H. (2016). Impact of Dietary Fibers on Nutrient Management and Detoxification Organs: Gut, Liver, and Kidneys. *Advances in Nutrition*, *7*(6), 1111–1121. https://doi.org/10.3945/an.116.013219

Kim, G. D., Kim, B. W., Jeong, J. Y., Hur, S. J., Cho, I. C., Lim, H. T., & Joo, S. T. (2011). Relationship of Carcass Weight to Muscle Fiber Characteristics and Pork Quality of Crossbred (Korean Native Black Pig × Landrace) F2 Pigs. *Food and Bioprocess Technology*, *6*(2), 522–529. https://doi.org/10.1007/s11947-011-0724-2
Li, H., Yin, J., Tan, B., Chen, J., Zhang, H., Li, Z., & Ma, X. (2021). Physiological function and application of dietary fiber in pig nutrition: A review. *Animal Nutrition*, *7*(2), 259–267. https://doi.org/10.1016/j.aninu.2020.11.011
Ma, X., Zhang, X., and Guo, Y. (2002). Effects of dietary fibre on nutrient digestibility and fecal characteristics of growing pigs. *Asian-Australasian Journal of Animal Sciences*, 15(4): 554-557.
Maes, D. G. D., Dewulf, J., Piñeiro, C., Edwards, S., & Kyriazakis, I. (2020). A critical reflection on intensive pork production with an emphasis on animal health and welfare. *Journal of Animal Science*, *98*(Supplement_1), S15–S26. https://doi.org/10.1093/jas/skz362
Makishima, M., Okamoto, A. Y., Repa, J. J., Tu, H., Learned, R. M., Luk, A., Hull, M. V., Lustig, K. D., Mangelsdorf, D. J., & Shan, B. (1999, May 21). Identification of a Nuclear Receptor for Bile Acids. *Science*, *284*(5418), 1362–1365. https://doi.org/10.1126/science.284.5418.1362
Mateos, G., Jiménez-Moreno, E., Serrano, M., & Lázaro, R. (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. *Journal of Applied Poultry Research*, *21*(1), 156–174. https://doi.org/10.3382/japr.2011-00477
Meyer, A., (2015). CCM for fattening pigs. Landwirtschaftskammer Niedersachsen https://www.lwk-niedersachsen.de/index.cfm/portal/1/nav/753/article/26477.html
Millet, S., Raes, K., De Smet, S., & Janssens, G. P. (2005). Evaluation of corn cob mix in organic finishing pig nutrition. *Journal of the Science of Food and Agriculture*, *85*(9), 1543–1549. https://doi.org/10.1002/jsfa.2148
Njideka, B. E., Chijioke, M. B., Chioma, O. N., Nnennaya, A. N., & Iheduzaju, P. A. (2020). Maize cob as dietary fiber source for high-fiber biscuit Primary tabs. GSC Biological and Pharmaceutical Sciences, 12(1), 138–144. https://doi.org/10.30574/gscbps.2020.12.1.0203
Morozov, S., Isakov, V., & Konovalova, M. (2018). Fiber-enriched diet helps to control symptoms and improves esophageal motility in patients with non-erosive gastroesophageal reflux disease. *World Journal of Gastroenterology*, *24*(21), 2291–2299. https://doi.org/10.3748/wjg.v24.i21.2291
Ogunniyi, L., & Omoteso, O. (2011). Economic Analysis of Swine Production in Nigeria: A Case Study of Ibadan Zone of Oyo State. *Journal of Human Ecology*, *35*(2), 137–142. https://doi.org/10.1080/09709274.2011.11906399
Ojediran, T. K., Bamigboye, D., Olonade, G., Ajayi, A., and Emiola, I. A. (2019). Growth response, cost benefit, carcass characteristics and organoleptic properties of pigs fed biscuit dough as a replacement for maize. *Acta Fytotechnica Et Zootechnica*, *22*(2), 58–63. https://doi.org/10.15414/afz.2019.22.02.58-63
Ojediran, T. K., Fawamide, T., Babajide, N., Ajayi, A., Shittu, M. D., and Emiola, I. A. (2020). Haematological parameters, organ weight and villi morphometrics of weaner pigs fed biscuit dough. *Polish journal of natural sciences*, 35(2): 141–150
Patráš, P., Nitrayová, S., Brestenský, M., & Heger, J. (2012). Effect of dietary fiber and crude protein content in feed on nitrogen retention in pigs1. Journal of Animal Science, 90(suppl_4), 158–160. https://doi.org/10.2527/jas.53837
Patricia, J. J. and Dhamoon, A. S. (2022). Physiology, Digestion. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK544242/
Peloso, J., Lopes, P., Gomide, L., Guimarães, S., & Carneiro, P. (2010). Carcass and ham quality characteristics of heavy pigs from different genetic groups intended for the production of dry-cured hams. *Meat Science*, 86(2), 371–376. https://doi.org/10.1016/j.meatsci.2010.05.017
Regiane, R. S., Ajay, A., Petra J. R., Monique, H. G., Tersteeg-Zijderveld, P. A., and Johanna, F. (2015) Quantitative histo-morphometric analysis of heat-stress-related damage in the small intestines of broiler chickens. *Avian Pathology*, 44:1, 19-22 https://doi.org/10.1080/03079457.2014.988122
Revilla, P., Alves, M. L., Andelković, V., Balconi, C., Dinis, I., Mendes-Moreira, P., Redaelli, R., Ruiz de Galarreta, J. I., Vaz Patto, M. C., Žilić, S., & Malvar, R. A. (2022). Traditional Foods From Maize (Zea mays L.) in Europe. *Frontiers in Nutrition*, *8*. https://doi.org/10.3389/fnut.2021.683399
Reynolds, A. N., Akerman, A. P., & Mann, J. (2020). Dietary fibre and whole grains in diabetes management: Systematic review and meta-analyses. *PLOS Medicine*, *17*(3), e1003053. https://doi.org/10.1371/journal.pmed.1003053
Samanya, M., & Yamauchi, K. E. (2002). Histological alterations of intestinal villi in chickens fed dried Bacillus subtilis var. natto. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, *133*(1), 95–104. https://doi.org/10.1016/s1095-6433(02)00121-6
Shen, Y. B., Weaver, A. C., Kim, S. W., and Zhu, J. J. (2014). Effect of dietary fibre on swine growth performance, intestinal morphology, and nutrient digestibility during grow-finish period using meta-analysis approach. *Journal of animal science*, 92(3): 1093-1102.
Soliman, G. A. (2019). Dietary Fiber, Atherosclerosis, and Cardiovascular Disease. *Nutrients*, *11*(5), 1155. https://doi.org/10.3390/nu11051155
Stewart, L. L., Kil, D. Y., Ji, F., Hinson, R. B., Beaulieu, A. D., Allee, G. L., Patience, J. F., Pettigrew, J. E., & Stein, H. H. (2013). Effects of dietary soybean hulls and wheat middlings on body composition, nutrient and energy retention, and the net energy of diets and ingredients fed to growing and finishing pigs1. *Journal of Animal Science*, *91*(6), 2756–2765. https://doi.org/10.2527/jas.2012-5147
Válková, V. (2012). Sensory Evaluation of Pork Flavor. In Handbook of Meat, Poultry and Seafood Quality, L.M.L. Nollet (Ed.). https://doi.org/10.1002/9781118352434.ch18
Wang, L., Beltranena, E., & Zijlstra, R. (2016). Diet nutrient digestibility and growth performance of weaned pigs fed sugar beet pulp. *Animal Feed Science and Technology*, 211, 145–152. https://doi.org/10.1016/j.anifeedsci.2015.11.005
Wu, C., Hua, Q., & Zheng, L. (2020). Generation of Myeloid Cells in Cancer: The Spleen Matters. *Frontiers in immunology*, *11*, 1126. https://doi.org/10.3389/fimmu.2020.01126
Xie, L., Qin, J. T., Rao, L., Cui, D. S., Tang, X., Xiao, S. J., Zhang, Z. Y., & Huang, L. S. (2023). Effects of carcass weight, sex and breed composition on meat cuts and carcass trait in finishing pigs. *Journal of Integrative Agriculture*, *22*(5), 1489–1501. https://doi.org/10.1016/j.jia.2022.08.122
Xu, Z. R., Hu, C. H., Xia, M. S., Zhan, X. A., & Wang, M. Q. (2003). Effects of dietary fructooligosaccharide on digestive enzyme activities, intestinal microflora and morphology of male broilers. *Poultry science*, *82*(6), 1030–1036. https://doi.org/10.1093/ps/82.6.1030
Zhang, Y., Han, Y., Liu, X., and Wang, Y. (2019). The effect of low protein and high fibre diets on liver lipid metabolism in growing pigs. *Journal of animal physiology and animal nutrition*, 103(1): 225-232.
Zou, Y., Xiang, Q., Wang, J., Wen, X., Liu, Y., and Yang, X. (2019). Effects of dietary fibre on the cecal microbiota community profile and short-chain fatty acid production in the growing pig. *Journal of agricultural and food chemistry*, 67(50): 13950-13958.