GROWTH, HEALTH STATUS AND COST BENEFIT ANALYSIS OF WEANER PIGS FED DIET SUPPLEMENTED WITH MALTODEXTRIN

***Adesehinwa, O. A.,[1] Boladuro, B. A.,[2] Makanjuola, B. A.,[2] Sorunke A. O.,[2] Bolaji, A. A.,[2] Agbede, J. O.[1] and Adesehinwa, A. O. K.[2]**
[1]*Department of Animal Production and Health, Federal University of Technology, Akure*
[2]*Institute of Agricultural Research and Training, Obafemi Awolowo University, Ibadan*
**Corresponding Author: koredeade82@gmail.com*

https://dx.doi.org/10.4314/gjansci.v16i1.1

ABSTRACT
This study evaluated the influence of maltodextrin in the diet of weaned pigs on growth, backfat thickness, haematology, serum biochemical and cost benefit indices. A total of 54 weaned pigs which are Large white × Landrace crossbred pigs with average weight of 9.35±2.36 kg were used for this study. They were randomly allotted to three dietary treatments (T1 - basal diet, T2 – 500 g/tonne maltodextrin inclusion, T3 – 1 kg/tonne maltodextrin inclusion) with three replicates each and six animals per replicate in a completely randomized design. The body weight gains of the pigs were not significantly (P>0.05) affected by the dietary treatments. They were 23.65, 25.92 and 24.63 kg in T1, T2 and T3 respectively. At the 6th week of the study, the feed conversion ratio (FCR) was significantly (P<0.05) influenced by diet and were 3.62, 4.26 and 3.81 in T1, T2 and T3 respectively. However, the FCR at the 13th week was not significant (P>0.05) among the treatments. The high-density lipoprotein cholesterol was significantly higher in T2 (56.33 mg/dL) and T3 (52.00 mg/dL) than in T1 (46.00 mg/dL) fed pigs. The backfat thickness and all the haematological indices measured were not significantly (P>0.05) influenced by the dietary treatment. The feed cost per weight gain improved with inclusion of maltodextrin from ₦1,213.03 in T1 to ₦1,153.77 in T2 and ₦1,120.75 in T3. The supplementation of maltodextrin in the diet of weaned pigs did not negatively influence the growth and the health status of the animals.

Keywords: *Health Status, Maltodextrin, Postweaning performance, Feed utilization, Blood profile*

INTRODUCTION

Weaning is one of the most critical stages in pig's life because of the need to adjust to dietary and environmental changes. These changes could have adverse effect on the intestinal and immune systems resulting in impaired health and growth particularly during the first few weeks post-weaning. At weaning, the sows' milk is replaced by a dry and less digestible starch-based diet (Williams, 2003), resulting in significantly reduced energy intake for epithelial structure maintenance (Pluske *et al*., 1996), reduced transmucosal resistance (Spreeuwenberg *et a*l., 2001; Boudry *et al*., 2004), and increased secretory activity in the small intestine (Boudry *et al*., 2004). With the underdeveloped innate and adaptive immune systems of the weaned pigs, damage to the epithelial layers also reduces the ability of nutrients to be digested and absorbed into the blood stream which increases the substrates available for pathogen proliferation (Pluske *et al.,* 2002). These biological changes have short and long-term effects on subsequent performance of pig in terms of growth and well-being. As a result of this, it is important that swine producers use appropriate health, nutrition, and management strategies to minimize the adverse effects of weaning stress so as to improve productivity.

A nutritional strategy to promote an early feed consumption after weaning is the use of highly palatable and digestible ingredients in the post-weaning diet, such as milk-derived products, or highly digestible cereal or animal origin protein sources (Solà-Oriol *et al.,* 2009). Apart from the main ingredients, non-nutritive feed additives, such as zinc oxide, acidifier, flavour and antibiotics are often incorporated to stimulate gut health and digestive capacity (Heo *et al.,* 2013). Hence, the need for an alternative non-conventional feed additive. Due to the adaptive nature of piglet's digestive system to milk components, post weaning diets have been formulated with lactose-rich ingredient that stimulate the intake of feed, help diet transitions (Berrocoso *et al*., 2012), and increase nutrient digestibility (O'Doherty *et al*., 2005), thereby mitigating the decrease in post weaning performance. Studies by Mahan and Newton (1993) and Oliver *et al*. (2002) have shown that it is possible to use hydrolyzed corn starch (Maltodextrin) as replacement for lactose in diets of infants without adversely affecting performance.

Notably, one of the main sources of energy for an infant's development and growth comes from carbohydrates. Maltodextrins (MDs) are a class of carbohydrates (CHOs) industrially produced by enzymatic or acid hydrolysis of the starch, followed by purification and spray drying (Takeiti *et al*., 2010). Studies have shown that maltose and maltodextrin are digested by a set of enzymes called maltases and are grouped into sucrase–isomaltase and maltase–glucoamylase complexes (Quezada-Calvillo *et al.,* 2007). These enzymes are responsible for about 70 and 20% of the hydrolysis of those carbohydrates respectively (Pivetta *et al*., 2014). Maltodextrin has the ability to lower the pH of the contents of the rectal cavity and has been implicated in lowering the total coliform and *E. coli* populations in the caecum thus, having a prebiotic effect (Pivetta *et al*., 2014). In addition, it has been reported to be effective in partially or totally (Augusto *et al*., 2011; Pivetta *et al*., 2014) substituting lactose in the feed of weaned piglets. Lactase activity has been reported to be lower than maltase activity in weaner pigs (Kidder, 1980), hence, maltodextrin supplementation in the diet of weaner pigs might induce the synthesis of maltase through the modulation of enzyme activity exerted by the substrate with improved performance. This study assessed the influence of supplementing the diet of weaned pigs with varying level of maltodextrin on the performance, back fat thickness, cost benefit and health status of the weaned pigs in a tropical environment.

MATERIALS AND METHODS

Study location and duration

This study was carried out at AK Research Farms, Eleyele, Ibadan, Oyo State, Nigeria with daily temperature ranging between 25 - 35°C and annual rainfall of 1800 mm (Victory *et al.,* 2022). The study lasted 91 days.

Experimental animals and management

Fifty-four weaned piglets that were 8 weeks old (Large white x Landrace crosses) with mean weight of 9.35±2.36 kg were used for the experiment. They were administered 0.2 - 0.3 mg/kg of ivermectin injection sub-cutaneously against internal and external parasites before the commencement of the experiment. The animals were housed in open sided cross ventilated pens with concrete floor under good management practices. The pens were equipped with concrete water troughs and Big Dutchman's semi-automatic feeder. Water and feed were supplied *ad libitum* throughout the experimental period. Daily routine practices carried out included feeding, watering, waste disposal, washing of pens and general observation of the animals' welfare.

Experimental design

The pigs were randomly allotted into 3 dietary treatments labelled T1, T2 and T3 in a completely randomized design (CRD). Each treatment was replicated 3 times with 6 animals per replicate. The diet of T1 (control/basal diet) was formulated to meet the nutrients requirements as recommended by the National Research Council (2012) for weaned pigs raised in tropical environment (Table 1). Pigs in T2 were fed basal diet with 500 g/tonne maltodextrin while T3 contained the basal diet with an inclusion rate of 1 kg/tonne maltodextrin.

Data Collection

The feed intake was estimated daily by subtracting the weight of the leftover feed from that of the feed given. The body weight of the pigs was determined weekly using a Yubo Single Desk 3tons Floor weighing platform scale manufactured by Changzhou Yubo Electronic Scale Co., Ltd. The weight gain was calculated as the difference between the initial weight and the final weight. The feed conversion ratio (FCR) was computed as the ratio of feed intake to weight gain.

Table 1: Percentage Composition of Basal Diet

Ingredients	Quantity %
Maize	40.00
Groundnut cake	25.00
Wheat offal	10.00
Corn bran	16.00
Fish meal	2.50
Limestone	2.00
Bone meal	2.00
Lysine	0.40
Methionine	0.325
Salt	0.40
Starter Premix	0.25
Toxin binder	0.05
Multi enzyme	0.05
Lavaricide	0.025
Palm oil	1.00
Total	100
Calculated Composition	
Metabolizable energy (Kcal/kg)	2650
Crude fiber (%)	5.73
Crude protein (%)	19.67

The proximate composition of the samples of the three diet were determined using the recommended procedures described by Association of Official Analytical Chemists (AOAC, 2010). The backfat thickness was measured across the treatment at the 12th week of the study using the ultrasonic probe technique described by Fortin *et al.* (1980) and modified by Jiang *et al.* (2014). The ultrasonic probe technique works on the principle of reflection of sound wave. The calibration of the instrument was based on the assumption that the ultrasonic sound waves travels through fatty tissue at a velocity of 1480 m/s. At the end of the study, the backfat thickness was taken off the midline over the last rib using ultrasound gel on the probe. This was done using the Dramiski ultrasound scanner manufactured by Dramiski Technology, Poland.

At the end of the feeding trial, pigs were randomly selected from each treatment and sampled for blood through the jugular vein into clinical sample bottles for analysis using hypodermic syringe and needle. The blood sampled for serum biochemistry analysis were collected into sterile plain sample bottles without anti-coagulant while those for haematological analysis were sampled into bottles with anti-coagulant (EDTA) to prevent the blood from clotting. The sampling was done in the morning before feeding. About 5 ml of blood samples were collected from each animal and were stored in iced flask till it was delivered to the laboratory some minutes after collection. The blood sampled for haematology were analysed for packed cell volume (PCV), haemoglobin concentration, erythrocyte count, leucocyte count, platelets, lymphocytes, neutrophils, monocytes, eosinophils, mean corpuscular haemoglobin concentration (MCHC), mean corpuscular haemoglobin (MCH) and mean cell volume (MCV). For serum biochemical analysis, the sampled blood was centrifuged for 20 - 30 min at 4000 rpm to separate the serum from the cells. The serum was analysed for total protein, albumin, aspartate aminotransferase (AST), alanine amino transferase (ALT), blood urea nitrogen, creatinine, glucose, total cholesterol, high density lipoprotein cholesterol and triglyceride. The globulin, albumin-globulin ratio (A:G) and low density lipoprotein cholesterol were estimated.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) procedures using the General Linear Model procedures of SAS (2002). The means among variables that were significant were separated using the Duncan's Multiple Range (DMR) Test.

Table 2: Proximate Composition of Experimental Diet

Sample	T1	T2	T3
Crude Protein (%)	19.43	19.63	19.84
Ether Extract (%)	3.79	3.87	3.83
Crude Fibre (%)	3.60	3.56	3.52
Ash (%)	5.59	5.46	5.35
Moisture (%)	11.36	11.19	11.14
Gross Energy (Kcal/g)	4.02	4.03	4.04
Nitrogen free extract (%)	67.60	67.60	67.48

RESULTS AND DISCUSSION

The performance of weaned pigs fed different levels of maltodextrin till week 6 of the experiment is as highlighted in Table 3. At the 6th week of the experiment no significant difference was observed in the body weight, feed intake and weight gain among the treatments. The weight gains were 8.68, 7.24 and 7.75 kg in T1, T2 and T3 respectively at week 6. However, the feed conversion ratio (FCR) significantly differs among the treatments. The group fed with diet containing 500 g/tonne maltodextrin (T2) had the significantly ($P<0.05$) highest FCR (4.26) but was not significantly ($P>0.05$) different from group fed with 1 kg/tonne maltodextrin, T3 (3.81). The FCR of T2, however, differed significantly ($P<0.05$) from that of T1 fed pigs, control diet, (3.62.). The FCR of T1 and T3 were however not significantly ($P>0.05$) different. At the 13th week of the study, the results obtained as indicated in Table 4 showed that the feeding of varying levels of maltodextrin to weaned pigs in this study did not significantly ($P>0.05$) influence all the growth indices measured. The final weights 2 (after 13 weeks of study) were 33.15, 35.20 and 33.89 kg in T1, T2 and T3 respectively. The average daily feed intake after the 13 weeks of study ranged from 1.11 kg in the group fed control diet (T1) and 1.21 kg in T2 diet. At the 13th week of the study, no significant ($P>0.05$) difference was observed in the FCR among the treatments. However, Pigs in T2 had the highest (4.23) FCR which is the treatment with least conversion efficiency, while the lowest was 4.11 recorded in the group fed T3. This corroborates the findings of Hauptli *et al.* (2016) who reported no significant effect of feeding weaner pigs with maltodextrin on weight gain and feed conversion. Pivetta *et al.* (2014) also reported that the inclusion of maltodextrin on the diet of weaned pigs did not compromise the performance of the pigs but depressed feed intake. The significant difference seen between the FCR of T1 and T2 fed pigs at week 6 may suggest that feeding maltodextrin may only be useful for a short period postweaning. The reports of O'Doherty *et al.* (2010) and Kim *et al.* (2010) suggest that maltodextrin improve the performance of weaned pigs from first week of inclusion and was identified to have similar effects with lactose. However, there may be need to ascertain the effect of feeding maltodextrin for longer periods on the performance of the pigs.

The thickness of back fat in weaner pig is related to growth and reproductive indices (Roongsitthichai and Tummaruk, 2014). The backfat thickness of pigs fed varying levels of maltodextrin in the diet is as shown in Figure 1. The backfat thickness of the weaner pigs were not significantly influence by the inclusion of maltodextrin in the diet. They were 8.50, 10.25 and 9.75 mm in T1, T2 and T3 fed pigs respectively.

Table 3: Performance of Weaned Piglets Fed Different Levels of Maltodextrin at Week 6

Parameters	T1	T2	T3	SEM
Initial Weight (kg)	9.50	9.28	9.26	0.91
Final Weight 1 (kg)	18.17	16.52	17.0	1.76
Weight Gain (kg)	8.68	7.24	7.75	0.91
Average Daily Gain (g)	206.60	172.36	184.47	21.6
Feed Intake (kg)	30.83	30.88	29.15	2.94
Average Daily Feed Intake (g)	734.10	735.23	721.16	69.97
Feed conversion Ratio	3.62^b	4.26^a	3.81^{ab}	0.10

$^{a, b}$ Means with different superscript across the row are significantly different at α=0.05
T1 - Control (Without maltodextrin); T2 – 500 g/tonne maltodextrin inclusion; T3 – 1 kg/tonne maltodextrin inclusion; Final Weight I - Weight after six weeks of study

Table 4: Performance of Weaned Piglets Fed Different Levels of Maltodextrin at Week 13

Parameters	T1	T2	T3	SEM
Initial Weight (kg)	9.50	9.28	9.26	0.91
Final Weight 2 (kg)	33.15	35.20	33.89	2.07
Weight Gain (kg)	23.65	25.30	24.63	1.29
Average Daily Gain (g)	0.26	0.28	0.27	0.02
Feed Intake (kg)	101.20	109.73	102.46	7.63
Average Daily Feed Intake (Kg)	1.11	1.21	1.13	0.08
Feed conversion Ratio	4.20	4.23	4.11	0.17

T1 - Control (Without maltodextrin); T2 – 500 g/tonne maltodextrin inclusion;
T3 – 1 kg/tonne maltodextrin inclusion; Final Weight 2 - Wieght after six weeks of study

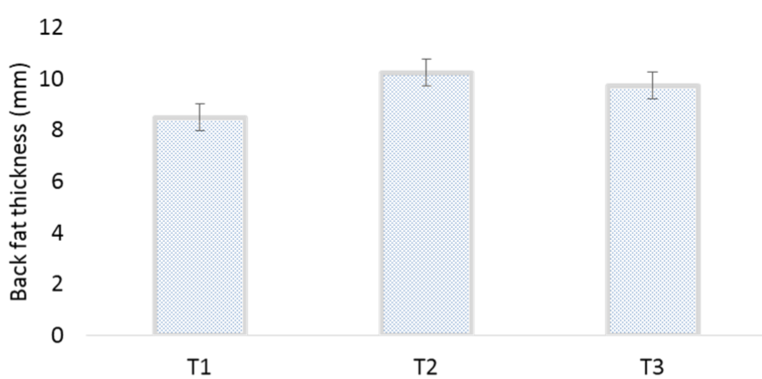

Fig 1: Back fat thickness (mm) thickness of pigs fed varying levels of maltodextrin in the diet .
T1- Control (without maltodextrin)
T2 - 500g/tonne maltodextrin inclusion
T3 - 1kg/tonne maltodextrin inclusion

Haematological and serum biochemical assays play crucial roles in assessing the physiological and health status of animals (Adenkola *et al.*, 2009; Etim, 2014; Koomkrong *et al.,* 2017). The haematology indices of weaner pigs fed varying levels of maltodextrin is as presented in Table 5. No significant (P>0.05) effect of the dietary treatments were observed on the haematological indices measured in this study. Similarly, Pivetta *et al*. (2014) noted that animals fed maltodextrin at inclusion rate above those in this study reported no significant interaction between diet with maltodextrin and that of fructooligosaccharides for all the haematological parameters measured. Although not significantly (P>0.05) notable, maltodextrin had lowering effect on the levels of haematological parameters measured in this study. The packed cell volume (PCV) was 38.00% in the animals on the control diet (T1), 33.00% in animals fed 0.5 kg/tonne maltodextrin in the diet (T2) while those fed 1 kg/tonne maltodextrin in the diet (T3) had 35.33%. Haemoglobin ranged from 10.67 to 12.40 g/dL in T2 and T1 respectively. The erythrocyte count also referred to as red blood cell (RBC) were 6.05, 5.23 and 5.80 µL in T1, T2 and T3 respectively. The eosinophils were 4.67, 3.33 and 2.33 % in T1, T2 and T3 respectively. Mean corpuscular haemoglobin concentration (MCHC) reduced from 32.64 g/dL in T1 to 32.32 g/dL in T2 and 31.90 g/dL in T3. Similarly, MCH reduced from 20.83 pg in T1 to 20.39 pg in T2 and 19.47 pg in T3. The reducing effect of maltodextrin on the haematological indices especially the packed cell volume, haemoglobin and red blood cells calls for a monitoring in the use of maltodextrin as a reduction below certain levels will suggest anaemia in the piglets. The values obtained for all the haematological indices in this study fall within the normal physiological range of a weaner pig (Merck Manual, 2012).

The serum biochemicals are important biomakers which could be suggestive of the impact of external factors such as plane of nutrition on the functionality of tissues, organs and body systems as a whole (Adenkola *et al.*, 2009; Koomkrong

Table 5: Haematological parameters of weaner pigs fed varying levels of maltodextrin

Parameters	T1	T2	T3	SEM
Packed cell volume (%)	38.00	33.00	35.33	1.55
Haemoglobin (g/dL)	12.40	10.67	11.27	0.50
Erythrocytes Count (µL)	6.05	5.23	5.80	0.32
Total Leucocytes (µL)	4400.00	4433.33	4300.00	261.82
Platelets (µL)	169666.67	116333.33	103333.33	17894.58
Lymphocytes (%)	49.33	48.33	49.33	1.22
Neutrophils (%)	46.33	45.00	45.33	0.96
Monocytes (%)	3.00	3.33	2.33	0.35
Eosinophil (%)	4.67	3.33	4.33	0.48
MCHC (g/dL)	32.64^{b}	32.32^{ab}	31.90^{a}	0.14
MCH (pg)	20.83	20.39	19.47	0.40
Mean cell volume (fL)	63.82	61.02	62.65	1.10

T1 - Control (Without maltodextrin); T2 – 500 g/tonne maltodextrin inclusion; T3 – 1 kg/tonne maltodextrin inclusion; MCHC - Mean corpuscular haemoglobin concentration; MCH - Mean corpuscular haemoglobin

Table 6: Serum Biochemical parameters of weaner pigs fed varying levels of Maltodextrin

Parameters	T1	T2	T3	SEM
Total protein (g/dL)	7.00	7.20	7.40	0.11
Albumin (g/dL)	2.90	3.07	3.25	0.06
Globulin (g/dL)	4.10	4.13	4.15	0.06
RATIO	0.71	0.74	0.78	0.01
AST (IU/l)	44.00	47.00	47.00	2.58
ALT (IU/l)	38.67	39.67	40.50	1.95
Blood urea nitrogen (mg/dL)	8.43	8.83	8.80	0.12
Creatinine (mg/dL)	0.77	0.80	0.80	0.01
Glucose (mg/dL)	78.33	82.00	84.50	1.52
Total cholesterol (mg/dL)	91.00	93.67	96.50	1.78
High density lipoprotein (mg/dl)	46.00^{c}	56.33^{a}	52.00^{b}	1.14
Triglyceride (mg/dL)	79.00	84.00	81.50	0.87
Low density lipopretein (mg/dL)	29.20	20.53	28.20	1.57

$^{a, b, c}$ Means with different superscript across the row are significantly different at α=0.05
T1 - Control (without maltodextrin); T2 – 500 g/tonne maltodextrin inclusion;
T3 – 1 kg/tonne maltodextrin inclusion; AST - Aspartate transaminase; ALT - Alanine aminotransferase

Table 7: Cost-Benefit Analysis of Maltodextrin Supplementation in Diet of Weaner Pigs

Parameters	T1	T2	T3	SEM
Cost of feed per kg (₦/kg)	243.36	243.58	243.8	0.06
Total cost of feeding (₦)	24626.95	24626.96	24980.82	1857.51
Average Daily Feed Intake (kg)	1.11	1.21	1.13	0.08
Average cost of feed/day (₦)	270.63	293.72	274.51	20.41
Feed conversion Ratio	4.20	4.23	4.11	0.17
Feed Cost/Weight Gain (₦/kg)	1021.30	1029.53	1001.75	40.82

T1 - Control (Without maltodextrin); T2 – 500 g/tonne maltodextrin inclusion;
T3 – 1 kg/tonne maltodextrin inclusion; Dollar to Naira- $1 = ₦403

et al., 2017). The serum biochemical indices of piglets fed diet containing different inclusion levels of maltodextrin is highlighted in Table 6. The varying inclusion levels of maltodextrin in the diets presented to weaner pigs in this study did not significantly influence the serum biochemical indices assayed in this study except the High-density lipoprotein (HDL) cholesterol. High density lipoprotein (HDL) cholesterol was significantly ($P<0.05$) highest (56.33 mg/dL) in T2 fed diet containing 500 g/tonne maltodextrin and different from 46.00 and 52.00 mg/dL recorded in T1and T3 respectively. The level of HDL in the serum increased with inclusion of maltodextrin in the diet. The maltodextrin had a hypolipidemic effect (Hassan *et al.,* 2014) on the pigs. This corroborates the report of Inglett and Grisamore (1991) who stated that the inclusion of maltodextrin in the diet has the potential to reduce bad fat (LDL) and increase good fat (HDL). This is made possible by the action of the beta-glucan component of maltodextrin which lowers total blood cholesterol by improving the HDL and lowering the LDL cholesterol (Inglett and Grisamore, 1991). This is beneficial to the health of the pig. The total proteins were 7.00, 7.20 and 7.40 g/dl in T1, T2 and T3 respectively. The Alanine aminotransferase increased from 38.97 IU/l in T1 to 39.67 IU/l in T2 and 40.50 IU/l in T3. The creatine was 0.77 mg/dL in T1 and 0.80 mg/dL in both T2 and T3 respectively.

Feed cost takes a very huge proportion of the variable cost of production in most livestock enterprises, that is why farmers are always on the lookout for cheaper and effective alternatives. Maltodextrin has been identified as cheaper alternative to other expensive carbohydrate sources especially in the diet of weaner pigs (Machado and Carvalho, 2015). The cost-benefit analysis of maltodextrin supplementation in the diet of weaner pigs is as presented in Table 7. The result showed no significant effect ($P>0.05$) of maltodextrin supplementation on overall cost of feeding. The average cost of feed consumed per day were ₦270.63, ₦293.72 and 274.51 in T1, T2 and T3 respectively. The feed cost per weight gain decreased across the treatments with increasing level of maltodextrin in the diet. Feed cost per weight gain were ₦1,213.03 in diet fed 0 % maltodextrin (T1), ₦1,153.77 in T2 fed 0.05 % maltodextrin and ₦1,120.75 in T3 fed 0.1 % maltodextrin. The cost per weight gain which was estimated to be higher for the control diet (T1) than in the diets supplemented with maltodextrin (T2 and T3) implies that the cost of including maltodextrin in the diet of pigs is beneficial considering that less is spent on feeding to produce a kg of live weight. This is an indication that the inclusion of maltodextrin diet is beneficial in terms of cost and health wise.

CONCLUSION

The inclusion of maltodextrin in the diet of weaned pigs did not negatively influenced the growth, back fat thickness and health status of the pigs. Maltodextrin had a hypolipidism effect on the pigs by increasing the high density lipoprotein (HDL) and reducing the low density (LDL). Its inclusion also improved the cost per weight of the gain of the pigs. Thus, maltodextrin can be added up to 0.1% in the diet of pigs in the tropics.

ACKNOWLEDGEMENT

The authors appreciate the management and staff of AK Research Farm, Eleyele, Ibadan, Nigeria for their assistance and contributions to this research work.

REFERENCES

A.O.A.C. (2010). Official Methods of Analysis.18th edition (W. Horwitz Editor). Association of Official Analytical Chemists. Washington, DC. pp 1094.

Adenkola, A. Y., Ayo, J. O., Sackey, A. K. B. and Adelaiye, A. B. (2009). Haematological and serum biochemical changes in pigs administered with ascorbic acid and transported by road for four hours during the harmattan season. *Journal of Cell Animal Biology*, *3*(2): 21-28.

Augusto, R. M. N., Berto, D. A., Lo Tierzo, V., Mello, G., Hauptli, L. and Lucchesi, L. (2011). Maltodextrina em rações de leitões desmamados com diferentes pesos: desempenho e morfometria intestinal. *Acta Scientiarum: Animal Sciences*, Maringá, 33(1): 41-46.

Berrocoso, J. D., Serrano, M. P., Cámara, L., Rebollar, P. G. and Mateos, G. G. (2012). Influence of diet complexity on productive performance and nutrient digestibility of weanling pigs. *Animal Feed Science and Technology*, 171(2-4): 214-222.

Boudry, G., Péron, V., Le Huerou-Luron, I., Lalles, J. P. and Seve, B. (2004). Weaning induces both transient and long-lasting modifications of absorptive, secretory, and barrier properties of piglet intestine. *The Journal of nutrition*, 134(9): 2256-2262.

Etim, N. N., Williams, M. E., Akpabio, U. and Offiong, E. E. (2014). Haematological parameters and factors affecting their values. *Agricultural Science*, 2(1): 37-47.

Fortin, A., Sim, D. W. and Talbot, S. (1980). Ultrasonic measurements of backfat thickness at different locations and positions on the warm pork carcass and comparisons of ruler and ultrasonic procedures. *Canadian journal of Animal Science*, *60*(3): 635-641.

Hauptli, L., Berto, D. A., Lo Tierzo, V., Augusto, R. M., Saleh, M. D. and Trindade Neto, M. A. D. (2016). Maltodextrine and oil in the diet of weaned piglets. *Boletim de Industria Animal, 73*(4): 339-346.

Hassan, A. M., Khalil, M. M., El-Gammal, R. E. and El Sherbini, Y. I. (2014). Chemical, physical and biological characteristics of low fat beef burger with maltodextrin. *Journal of Food and Dairy Sciences*, *5* (11): 795-811.

Heo, J. M., Opapeju, F. O., Pluske, J. R., Kim, J. C., Hampson, D. J. and Nyachoti, C. M. (2013). Gastrointestinal health and function in weaned pigs: a review of feeding strategies to control post-weaning diarrhoea without using in-feed antimicrobial compounds. *Journal of animal physiology and animal nutrition*, *97*(2): 207-237.

Inglett, G. E. and Grisamore, S. B. (1991). Maltodextrin fat substitute lowers cholesterol. *Food technology (USA)*.

Jiang XiaoBing, J. X., Zhang Liang, Z. L., Chen SiQing, C. S., Wang KeTian, W. K., Chen ZhuPing, C. Z., Chen Lei, C. L., Wang JinYong, W. J. and Zhu Li, Z. L. (2014). Ultrasound measurement of backfat thickness and longissimus muscle area in live swine: effects of equipment, personnel and pigs pose.: *Journal of Animal and Veterinary Advances*, 13(8): 506-513.

Kidder, D. E. and Manners, M. J. (1980). The level and distribution of carbohydrases in the small intestine mucosa of pigs from 3 weeks of age to maturity. *British Journal of Nutrition*, *43*(1): 141-153.

Kim, J. S., Shinde, P. L., Yang, Y. X., Yun, K., Choi, J. Y., Lohakare, J. D. and Chae, B. J. (2010). Effects of dietary lactose levels during different starter phases on the performance of weaning pigs. *Livestock Science*, *131*(2-3): 175-182.

Koomkrong, N., Boonkaewwan, C., Laenoi, W. and Kayan, A. (2017). Blood haematology, muscle pH and serum cortisol changes in pigs with different levels of drip loss. *Asian-Australasian Journal of Animal Sciences*, *30* (12): 1751.

Machado, C. A. and Carvalho, L. S. S. (2015). Maltodextrin in animal feed. *Revista Portuguesa de Ciências Veterinárias*, *110* (593/594): 14-16.

Mahan, D. C. and Newton, E. A. (1993). Evaluation of feed grains with dried skim milk and added carbohydrate sources on weanling pig performance. *Journal of Animal Science*, *71* (12): 3376-3382.

Merck Manual (2012). Haematologic reference ranges. *Mareck Veterinary Manual*. Retrieved from http://www.merckmanuals.com/

National Research Council. (2012). Nutrient requirements of swine, 11th edn. Washington, DC, USA: National Academies Press.

O'Doherty, J. V., Dillon, S., Figat, S., Callan, J. J. and Sweeney, T. (2010). The effects of lactose inclusion and seaweed extract derived from Laminaria spp. on performance, digestibility of diet components and microbial populations in newly weaned pigs. *Animal Feed Science and Technology*, *157*(3-4): 173-180.

O'Doherty, J. V., Nolan, C. S. and McCarthy, P. C. (2005). Interaction between lactose levels and antimicrobial growth promoters on growth performance of weanling pigs. *Journal of the Science of Food and Agriculture*, *85*(3): 371-380.

Oliver, W. T., Mathews, S. A., Phillips, O., Jones, E. E., Odle, J. and Harrel, R. J. (2002). Efficacy of partially hydrolyzed corn syrup solids as a replacement for lactose in manufactured liquid diets for neonatal pigs. *Journal of Animal Science*, Champaign, 80(1):143-153.

Pivetta, M. R., Berto, D. A., Amorim, A. B., Saleh, M. A. D., Pinheiro, D. F., Paulino, M. D. L. M. V. and Gonçalves, H. C. (2014). Use of maltodextrin and a prebiotic in the feed of weaned piglets. *Semina: Ciências Agrárias*, 35(4): 2129-2145.

Pluske, J. R., Pethick, D. W., Hopwood, D. E. and Hampson, D. J. (2002). Nutritional influences on some major enteric bacterial diseases of pig. *Nutrition Research Reviews*, 15(2): 333-371.

Pluske, J., Le Didivich, J. and Verstegen, M. (2003). Introduction. In Weaning the pig – concepts and consequences, *Wageningen Academic Publishers, The Netherlands*. pp. 15–16.

Quezada-Calvillo, R., Robayo-Torres, C. C., Ao, Z., Hamaker, B. R., Quaroni, A., Brayer, G. D., Sterchi, E. E, Baker, S. S. and Nichols, B. L. (2007). Luminal substrate "brake" on mucosal maltase-glucoamylase activity regulates total rate of starch digestion to glucose. *Journal of Pediatric Gastroenterology and Nutrition*, *45*(1), 32-43.

Roongsitthichai, A. and Tummaruk, P., (2014). Importance of backfat thickness to reproductive performance in female pigs. *The Thai Journal of Veterinary Medicine*, 44(2), pp.171-178.

SAS, 2002. Statistical Analysis software, Version 9.0. SAS Institute Incorporation, Cary, NC, USA.

Solà-Oriol, D., Roura, E. and Torrallardona, D. (2009). Feed preference in pigs: Effect of cereal sources at different inclusion rates. *Journal of Animal Science*, 87(2): 562 -570.

Spreeuwenberg, M. A. M., Verdonk, J. M. A. J., Gaskins, H. R. and Verstegen, M. W. A. (2001). Small intestine epithelial barrier function is compromised in pigs with low feed intake at weaning. *The Journal of nutrition*, 131(5): 1520-1527.

Takeiti, C. Y., Kieckbusch, T. G. and Collares-Queiroz, F. P. (2010). Morphological and physicochemical characterization of commercial maltodextrins with different degrees of dextrose-equivalent. *International Journal of Food Properties*, 13(2): 411-425.

Victory, G. O., Oyewole, A. L. and Olaitan, A. A. (2022). Climate-Smart Agricultural Practices at Oyo State-Nigeria. *South Asian Journal of Social Review*, 1(1): 1-7.

Williams, I. H. (2003). Growth of the weaned pig. Weaning the pig: concepts and consequences, *Wageningen Academic Publishers, The Netherlands*. pp. 17–31.