POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 35(2): 129–139, Y. 2020

EFFECTS OF PALM KERNEL MEAL-BASED DIET WITH OR WITHOUT ENZYME SUPPLEMENTATION ON GROWTH PERFORMANCE, ECONOMIC BENEFITS AND VILLI MORPHOMETRY OF WEANED PIGS

***Taiwo Ojediran*[1], *Samad Olayiwola*[2], *Michael Adeyeye*[3], *Ayodeji Ajayi*[4], *Isiak Emiola*[5]**

[1] ORCID: 0000-0003-1355-200X
[4] ORCID: 0000-0002-0992-1653
[1–3, 5] Department of Animal Nutrition and Biotechnology
[4] Department of Physiology
Ladoke Akintola University of Technology in Ogbomoso, Nigeria

Key words: weaned pigs, growth performance, enzyme, villi morphometry, economic indices, palm kernel meal.

Abstract

This study aimed to assess the effects of palm kernel meal (PKM) based diet with or without enzyme supplementation on growth response, cost benefits and villi morphometry of weaned pigs. Forty weaned male pigs with an initial weight of 7.85 ± 0.31 kg (Large white x Landrace) were divided into four dietary groups. The control diet (*A*) consist of only PKM based diet. In contrast, the three other PKM based diets *B*, *C* and *D* were supplemented with increasing doses of commercial feed enzyme (polyzyme) at an inclusion level of 0.1%, 0.2% and 0.3% respectively. The PKM had 91.58% dry matter, 15.75% crude protein, 21.42% crude fibre, 12.23% ether extract, 1.40% ash, 40.78% nitrogen-free extract and 3,030 kcal/kg metabolizable energy. The feed cost per kg ranges from ₦102.11 in diet *A* to ₦108.71 in diet *D* with a linear increase across dietary groups. The villi height was higher in those fed diets *A* than those fed diets *B–D*. In conclusion, polyzyme supplementation up to 0.30% does not improve weight gain and profit margin but reduced villi height. Therefore increased polyzyme use should be further researched in a 55% PKM based diet.

Address: Ayodeji Ajayi, Ladoke Akintola University of Technology in Ogbomoso, P. M. B. 4000, Ogbomoso, Nigeria, e-mail: aajayi22@lautech.edu.ng

Introduction

The use of palm kernel meal (PKM) in mono-gastric animals such as poultry and swine is limited due to the low activity of fibre digestive enzymes in their gastrointestinal tract (SHARMILA et al. 2014). Non-starch polysaccharides (NSPs) are complex carbohydrates with the sophisticated cell wall, other than starches found in food. They form the major part of dietary fibre and can be measured more precisely than total dietary fibre. Examples include cellulose, pectins, glucans, arabinans, arabinogalactans, galactans, mannans, and galactomannans. Non-starch Polysaccharides, being a carbohydrate, are a potential energy source and are indigestible by monogastric animals. Their fibrousness can result in reduced nutrient digestibility, increased feed conversion ratio and ultimately decreased animal performance (WENK 2001, NOBLET and LE GOFF 2001), although this is determined by fibre properties (LINDBERG 2014). Palm kernel cake (PKC) consist mainly of mannans, cellulose and xylans (WING-KEONG and KAI-KAI CHONG 2002) with mannans dominating its significant portion of NSP. It contains about 78% of mannans with β-mannan amounting up to 32.5% (OLADOKUN et al. 2016).

Numerous researches have been conducted to develop various means of increasing the nutritional contents of fibrous feedstock to reduce and or eliminate the constraints of utilizing them in mono-gastric diets. Physical, chemical, biological, or combination of these treatment methods have all been used in achieving this target (SHARMILA et al. 2014). However, the chemical and natural treatments of PKC seem to be more potent and improve the nutritive values of PKC in diets. One form of biological treatment used in improving the nutritive value of PKC in diets involves supplementation of the diets with exogenous enzymes that can breakdown the cell wall of NSPs present in PKC and liberate the nutrients entrapped within the cell wall. The treatment will enable the nutrients to be easily accessible to the animal for absorption, thereby enhancing their digestibility.

In recent time, there have been collective efforts tailored towards limiting the negative effect of dietary NSP in mono-gastric diets and improve the nutritive value of feedstuffs through the use of exogenous enzymes (SEKONI et al. 2008). The digestion of non-starch polysaccharides (NSPs) of the cell wall of PKC can be enhanced with the use of enzyme supplementation in monogastric diets (SOBOTKA et al. 2011). However, studies show that the supplementation of exogenous enzymes in diets containing PKC could improve its nutritive quality, and make it more available for animal use, especially poultry and swine (SEKONI et al. 2008, CHONG et al. 2008). Nevertheless, the use of a cocktail of enzymes is limited.

This study aimed to appraise the outcome of palm kernel meal-based diet with or without polyzme enzyme supplementation on growth response, cost benefits and villi morphometry of weaned pigs.

Materials and Methods

The experiment was carried out at the Ladoke Akintola University of Technology Teaching and Research Farm Piggery Unit, Ogbomoso. Ogbomoso lies on longitude $4^{0}16^{1}$ East of the Greenwich Meridian and Latitude $8^{0}10^{1}$ North of the equator. The region has a latitude between 300 and 600 meters above sea level. The mean annual temperature is about 27^{0}C while that of average rainfall is 1247 mm. The vegetation of the study area is in the derived savannah zone (OJEDAPO et al. 2009).

Forty weaned male pigs with an initial weight of 7.85 ± 0.13 kg (Large white x Landrace) were used for this experiment which lasted for seven weeks. The pigs used were from the same piggery unit where the experiment took place. The weaned pigs selected based on sex and weight were farrowed by 6 Large white sows mated by the same Landrace boar. Concrete floor experimental pens, feed troughs and drinkers used were washed and cleaned thoroughly before the introduction of the pigs to the pen and use of other materials. They were acclimatized and fed with weaner ration of 22% CP for a week before the commencement of the experiment. The pigs were weighed individually and assigned to four (4) dietary groups based on weight with ten (10) replicates per treatment. The animals were after that weighed every week until the end of the feeding trial. Feed and water also were given *ad libitum*.

The feedstuffs and test enzyme (Polyzme, an exogenous enzyme) used for the experiment was purchased from a reputable commercial feed store in Ogbomoso. The enzyme is a cocktail of mannanase, xylanase, cellulase, glucanase, phytase, amylase, pectinase, lipase, galactosidase and protease.

Four dietary formulations of palm kernel meal (PKM) basal diet, supplemented with or without enzyme supplementation were formulated for the weaned pigs. The control diet (*A*) consist of only PKM based diet with no enzyme supplementation. In contrast, the remaining three diets were supplemented with increasing dosages of commercial feed enzyme (polyzyme) at inclusion level of 0.1% [1 g kg^{-1} feed], 0.2% and 0.3% as diets *B*, *C* and *D* respectively as displayed by Table 1.

Table 1

Percentage composition of components of experimental diets

Ingredients [%]	Diet *A* 0.0% Polyzyme	Diet *B* 0.1% Polyzyme	Diet *C* 0.2% Polyzyme	Diet *D* 0.3% Polyzyme
Maize	15.00	15.00	15.00	15.00
Fish meal	3.00	3.00	3.00	3.00
Full fat soya	9.00	9.00	9.00	9.00
Palm kernel meal	55.00	55.00	55.00	55.00
Wheat offal	15.00	15.00	15.00	15.00
Bone meal	1.50	1.50	1.50	1.50
Limestone	1.00	1.00	1.00	1.00
*Premix	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Polyzyme [%]	0.00	0.10	0.20	0.30
Total	100.00	100.00	100.00	100.00
Calculated nutrients [%]				
Crude protein	19.93	19.93	19.93	19.93
Ether extract	6.35	6.35	6.35	6.35
Crude fibre	8.70	8.70	8.70	8.70
ME [MJ kg^{-1}]	11.36	11.36	11.36	11.36
Lysine	0.87	0.87	0.87	0.87
Methionine	0.40	0.40	0.40	0.40
Calcium	0.95	0.95	0.95	0.95

Explanations: ME – metabolizable energy; *premix composition: vitamin A – 12 500 000 IU; vitamin D_3 – 5 000 000 IU; vitamin E – 40 000 mg; vitamin K_3 – 2000 mg; vitamin B1 – 3000 mg; vitamin B_2 – 5500 mg; niacin – 55 000 mg; calcium pantothenate – 11 500 mg; vitamin B_6 – 5000 mg; vitamin B_{12} – 25 mg; folic acid – 1000 mg; biotin – 50 mg; choline chloride 500 000 mg; manganese – 300 000 mg; iron – 120 000 mg; zinc – 80 000 mg; copper – 8500 mg; iodine – 1500 mg; cobalt – 3000 mg; selenium – 120 mg; anti-oxidant – 120 000 mg (in every 2.5 kg package, at 2.5 kg per ton of feed)

Data were collected on growth performance indices, including feed intake, weight changes while the feed conversion ratio was calculated. Feed intake was measured individually as the differential between feed offered and feed left daily while the weight change or gain was taken weekly using a sensitive electronic scale. The feed conversion ratio was calculated as average feed intake divided by average weight gain. Economic indices were calculated as previously described (OJEDIRAN et al. 2017).

Feed cost/kg = sum (quantity of each ingredient – unit cost of each ingredient) %/100.

Feed cost per kg weight gain = feed cost/kg – total feed intake [kg]/ total weight gain.

Income per kg weight gain = selling price/kg – final weight per pig/ total weight gain [kg]

Profit per kg weight gain = income per kg weight – feed cost/kg weight gain

Economic efficiency of growth (EEG) = (profit per kg of weight gain/ feed cost per kg weight gain) · 100.

Morphometric characteristics of the jejunum, including the villus length and width, crypt depth and area, were determined. By the end of the experiment, four pigs were randomly selected from each treatment for jejunum evaluation and were starved overnight for 12 hours but allowed access to water *ad libitum*. The pigs were slaughtered by severing the jugular veins and were eviscerated to collect the jejunum portion at three different locations. The triplicate samples were fixed in 10% neutral buffered formalin labelled appropriately before further processing in an automatic tissue processor, embedded in paraffin wax and sectioned at 5 microns on a rotary microtome mounted on glass slides. The stepwise protocol for the automatic tissue processor for histological examination slide was done as previously described (SHEN et al. 2009, CARSON and CHRISTA 2009).

Only the villi considered adequate for measurements were counted. A villus is deemed to be sufficient when its base is embedded in the submucosa (10 x magnification); its body did not present any discontinuity or folds (4 x magnification), and simple columnar epithelium was present at the tip (40 x magnification). From each section, five randomly selected villi were measured in each slide per field, and five areas were used. Villi lengths, widths and cryptal depths were measured in microns (converted to cm) using top view software on the Amscope (MU900) camera.

A representative sample of the palm kernel meal used in the formulation was taken and analysed for proximate composition using the procedure of AOAC (2012). The metabolizable energy (ME) was calculated using the equation predicted by PAUZENGA (1985):

$$\text{metabolizable energy [kcal/kg]} = (37 \cdot \%CP) + (81.8 \cdot \%EE) + (35.5 \cdot \%NFE)$$

The data collected in this feed trial were subjected to analysis of variance (ANOVA) in a completely randomized design using SAS (2000) software package and means was separated using Duncan multiple range test of the same package.

Results

The proximate composition of palm kernel meal (PKM) used in this study is presented in Table 2. It had 91.58% dry matter, 15.75% crude protein, 21.42% crude fibre, 12.23% ether extract, 1.40% ash, 40.78% nitrogen-free extract and 3,030.85 kcal/kg (12.67 MJ kg^{-1}) metabolizable energy.

The growth performance of weaned pigs fed PKM based diet with or without enzyme supplementation is shown in Table 3. The results indicated that average daily feed intake (ADFI) was significantly different ($P < 0.05$), however, the average initial weight, average final weight, average daily weight gain and feed conversion ratio were not significantly influenced ($P > 0.05$). ADFI reduced linearly from pigs fed diets *A* to *D* except pigs fed diet *C* that had the highest value.

Table 4 shows the economic benefits of weaner pigs fed PKM based diet with and without enzyme supplementation. The feed cost per kg was significantly different ($P < 0.05$). It ranged from ₦102.11 in diet A to ₦108.71 in diet *D* with a linear increase across dietary groups. The values obtained for the feed cost per kg weight gain, income per kg weight gain, profit per kilograms of weight gain and the economic efficiency of increase were not significantly different ($P > 0.05$).

Intestinal morphology of grower pigs fed PKC based diet with and without enzyme supplementation is as shown in Table 5. The villus height was significantly affected ($P < 0.05$) by the dietary treatments. The villi width, cryptal depth and width were not significantly different ($P > 0.05$) across the groups. The villi height was considerably higher than those fed diets *B*–*D*.

Table 2

Chemical composition of palm kernel meal (PKM)

Nutrients	Percentage composition
Dry matter	91.58
Crude protein	15.75
Crude fibre	21.42
Ash	1.40
Ether extract	12.23
Nitrogen free extract	40.78
ME [MJ kg^{-1}]	12.67

Explanations: ME – metabolizable energy

Table 3

Growth performance of weaner pigs fed PKC based diet with and without enzyme supplementation

Parameters	Diet *A* 0.0% Polyzyme	Diet *B* 0.1% Polyzyme	Diet *C* 0.2% Polyzyme	Diet *D* 0.3% Polyzyme	SEM (±)
AIW [kg]	7.81	7.80	7.98	7.89	0.31
AFW [kg]	21.56	19.76	22.04	19.78	0.81
ADWG [kg]	0.28	0.24	0.29	0.24	0.01
ADFI [kg]	0.80^{b}	0.68^{c}	0.83^{a}	0.62^{d}	0.20
FCR	3.28	2.86	3.00	2.59	0.21

Explanations: $^{a, b, c, d}$ – means with different superscripts in the same row are significantly different ($P < 0.05$); AIW – average initial weight; AFW – average final weight; ADWG – average daily weight gain; ADFI – average daily feed intake; FCR – feed conversion ratio; SEM – group standard error of mean

Table 4

Economic indices of weaner pigs fed PKC based diet with and without enzyme supplementation

Parameters	Diet *A* 0.0% Polyzyme	Diet *B* 0.1% Polyzyme	Diet *C* 0.2% Polyzyme	Diet *D* 0.3% Polyzyme	SEM (±)
FC/kg [₦]	102.11^{d}	104.31^{c}	106.51^{b}	108.71^{a}	0.58
FC/kg WG [₦]	335.00	298.59	319.70	281.58	21.00
Income/kg WG [₦]	665.12	664.85	633.96	665.42	18.76
Profit/kgWG [₦]	330.13	366.27	314.26	383.83	12.21
EEG	115.61	128.25	104.27	138.90	8.47

Explanations: $^{a, b, c, d}$ – means with different superscripts in the same row are significantly different ($P < 0.05$); FC/kg – feed cost per kilogramme; FC/kg WG – feed cost per kilogramme weight gain; EEG – economic efficiency of gain; SEM – standard error of mean; ₦ – Nigerian naira

Table 5

Villi morphometry of weaner pigs fed PKC based diet with and without enzyme supplementation

Parameters [cm]	Diet *A* 0.0% Polyzyme	Diet *B* 0.1% Polyzyme	Diet *C* 0.2% Polyzyme	Diet *D* 0.3% Polyzyme	SEM (±)
Villi height	0.32^{a}	0.26^{b}	0.23^{b}	0.25^{b}	0.01
Villi width	0.04	0.04	0.03	0.04	0.00
Cryptal depth	0.15	0.16	0.13	0.17	0.01
Cryptal width	0.03	0.03	0.02	0.03	0.00

Explanations: $^{a, b}$ – means with different superscripts in the same row are significantly different ($P < 0.05$); SEM – standard error of the mean

Discussion

The palm kernel meal used was observed to contain similar crude protein, crude fibre and moisture contents as previously reported (ADESEHINWA 2009). However, the values obtained for ash, ether extract and nitrogen-free extract were different from those indicated by the same author. The shell content of palm kernel meal, which could be as high as 10% was reported earlier (ADESEHINWA 2007) to contribute a great deal to its high fibre content. The ether extract content, however, is a function of the oil extraction method used (BOATENG et al. 2008). The metabolizable energy of PKM in this current study is similar to that reported previously (ADESEHINWA 2007), which were different from that of the typical Malaysian PKC reported by SHARMILA et al. (2014). The difference may be attributed to the predominant method of oil extraction.

In this study, polyzyme® enzyme supplementation did not affect weight gain and feed conversation ration of weaned pigs. It was also observed that the enzyme does not necessarily increase the voluntary feed intake of the animals. Still, the previous study found that Avizyme® 1300 inclusion in 100 kg of 45% Cassava peel meal (CPM) based diet improved feed utilization and performance (ADESEHINWA 2007). Observation from this study is also contrary to the report that enzyme supplementation in pigs diet might improve feed conversion ratio without any significant difference in feed intake (AO et al. 2011), this author also reported that the inclusion of palm kernel meal in pig diet decreased the growth performance while carbohydrase cocktail supplementation counteracted the adverse effects caused by palm kernel meal addition in pig's diet. Another study on the response of weaned pigs to enzyme supplemented palm kernel cake in place of maize concluded that there were no differences between the total weight gain of weaned pigs on the control diet and those on diets with 40% PKC with and without enzyme supplementation (OLUFEMI and AKPODIETE 2010), this report is similar to the result of this present study, which indicated that 55% PKM in the diets of weaned pigs with and without enzyme supplementation does not adversely affect weight and feed conversation ratio.

Feed costs account for 65% to 75% of pig production expenses and significantly impact the profitability of pork producers; therefore, producing alternative sources of feed is essential (CHOI et al. 2015) because, the cost of corn, which is a significant component of animal feed, increased owing to the considerable demand for bio-ethanol and bio-fuel (DE GORTER et al. 2013). The increased feed cost per kg with increased polyzyme supplementation in this study could not be unexpected because the gross feed composition was the same except for the enzyme quantity added. However, despite the higher cost/kg of the supplemented diets to the control diet, the feed cost per weight gain, income per kilograms of weight gain, and profit per kg weight gain and economic efficiency of gain compared favourably. The result may suggest that the polyzyme supplementation in a 55% PKM based diet may be unnecessary. Previous report showed that reduction of feed cost was not only to obtain cheaper feed but also aimed at the derivation of best production performance with the cheaper feed (ADESEHINWA 2009), this author, therefore, concluded that the efficiency with which the feed was utilized was of significant importance, this was also observed in this study.

The morphometry of the intestine (jejunum) from this study indicates that the villus heights were lower in the supplemented group than the non-supplemented group (control diet *A*). The result of villi height in this current study agrees with the report of HEDEMANN et al. (2006), who attributed such decrease in weaned pigs to high soluble NSP content. It suggests the efficacy of polyzyme in this study. Nevertheless, insoluble NSP as observed in pigs fed diet with no polyzyme according to Hedemann et al. (2006) reduce transit time through the intestine and provide substrates that modulate the gut morphometry by increasing villi height. FREIRE et al. (2003) suggested that observed differences in gut morphology is explainable by differences in digesta transit time and gut microbial activities.

Also from the histo-morphometry report is the conclusion that inclusion of 55% PKC in weaner pig's diet affects the morphometry of the intestine of the test animals and enzyme supplementation of the diets has no counteracting effects on the intestine of the animals.

Conclusions

It can be concluded that polyzyme supplementation at between 0.1–0.3% does not improve weight gain and profit margin. Nevertheless, reduced villi height. Therefore, increased polyzyme use should be further researched in a 55% PKM based diet.

Accepted for print 3.03.2020

References

ADESEHINWA A.O. 2007. *Utilization of palm kernel cake as a replacement for maize in diets of growing pigs: effects on performance, serum metabolites, nutrient digestibility and cost of feed conversion.* Bulgarian Journal of Agricultural Sciences, 13: 593–600.

ADESEHINWA A.O. 2009. *Palm kernel cake supplemented with cassava flour waste as an energy source for pigs*. Revista Brasileira de Ciências Agrárias, 4(4): 479–484.

AO X., ZHOU TX., MENG QW., LEE JH., JANG HD., CHO JH., KIM IH. 2011. *Effects of a carbohydrase cocktail supplementation on the growth performance, nutrient digestibility, blood profiles and meat quality in finishing pigs fed palm kernel meal*. Livestock Science, 137 (1–3): 238–243.

AOAC. 2012. *Official methods of analysis* (19th ed). Association of Official Analytical Chemists, Arlington, VA, doi: http://10.4236/oalib.11009321.

BOATENG M., OKAI D., BAAH J., DONKOH A. 2008. *Palm kernel cake extraction and utilization in pig and poultry diets in Ghana*. Livestock Research for Rural Development, 20(7), http://www.lrrd.org/lrrd20/7/boat20099. htm.

CARSON FL., CHRISTA H. 2009. *Histotechnology: A self–instructional text (3 ed.). Hong Kong,* American Society for Clinical Pathology *Press*, pp. 2.

CHOI H.B., JEONG J.H., KIM D.H., LEE Y., KWON H., KIM Y.Y. 2015. *Influence of rapeseed meal on growth performance, blood profiles, nutrient digestibility and economic benefit of growing-finishing pigs*. Asian Australasian Journal of Animal Science, 28: 1345–1353.

CHONG C.H., ZULKIFLI I., BLAIR R. 2008. *Effects of dietary inclusion of palm kernel meal and palm oil, and enzyme supplementation on performance of laying hens*. Asian-Australasian Journal Animal Science, 21(7): 1053–1058.

DE GORTER H., DRABIK D., JUST D.R. 2013. *Biofuel policies and food grain commodity prices 2006-2012: All boom and no bust?* Agbioforum, 16(1): 1–13.

FREIRE J.P.B., DIAS R.I.M., CUNHA L.F., AUMAITRE A. 2003. *The effect of genotype and dietary fibre level on the ceacal bacterial activity of young piglets: digestive consequensies*. Animal Feed Science and Technology, 106: 119–130.

HEDEMANN M.S., ESKILDSEN M., LAERKE H.N., PEDERSEN C., LINDBERG J.E., LAURINEN P., BACH KNUDSEN K.E. 2006. *Intestinal morphology and enzymatic activity of newly weaned pigs fed contrasting fibre content rations and fibre properties*. Journal of Animal Science, 84: 1375–1386.

LINDBERG J.E. 2014. *Fibre effects in nutrition and gut health in pigs*. Journal of Animal Science and Biotechnology, 5(15): 1891–1895.

NOBLET J., LE GOFF G.I. 2001. *Effect of dietary fibre on energy value of feed for pigs*. Animal Feed Science and Technology, 90: 35–52.

OJEDAPO L.O., ADEDEJI T.A., AMEEN S.A., OLAYENI T.B., AMAO S.R. 2009. *Effect of strain and age on egg quality characteristics of two different strains of layer chicken kept in cages in the derived savanna zone of Nigeria*. Proceedings of 14th Annual Conference of Animal Science Association of Nigeria (ASAN), Sept. 14–17, LAUTECH Ogbomoso, Nigeria, pp. 1–3.

OJEDIRAN T.K., FASOLA M.O., OLADELE T.O., ONIPEDE T.L. EMIOLA I.A. 2017. *Growth performance, flock uniformity and economic indices of broiler chickens fed low crude protein diets supplemented with lysine*. Archivos de Zootecnia, 66(256): 543–550.

OLADOKUN A.A., WAHAB A.R., SUPARJO N.M. 2016. *Prospects of maximizing palm kernel cake utilization for livestock in Malaysia: A review*. Journal of Biology, Agriculture and Healthcare, 6(13): 65–69

OLUWAFEMI R.A., AKPODIETE O.J. 2010. *Response of weaned pigs to enzyme Supplemented palm kernel cake as a replacement for maize in their diets*. Proc 35th Conf. Nigerian Society for Animal Production University of Ibadan, Nigeria. 14–17 March 2010, pp. 311–314.

PAUZENGA U. 1985. *Feeding parent stock*. Zootenica International, pp. 22–24.

SAS Institute Incorporated. 1999. SAS/STAT. User's guide. Version 8 for Windows. Cary, NC, USA: SAS Institute Inc.

SHEN Y.B., PIAO X.S., KIM S.W., WANG L., LIU P., YOON I., ZHEN Y.G. 2009. *Effects of yeast culture supplementation on growth performance, intestinal health, and immune response of nursery pigs*. Journal of Animal Science, 87(8): 2614–2624.

SEKONI A.A., OMAGE J.J. BAWA G.S. ESUGA P.M. 2008. *Evaluation of enzyme (Maxigrain®)* Treatment of graded levels of Palm Kernel Meal (PKM) on nutrient retention. Pakistani Journal of Nutrition, 7(4): 614–619.

SHARMILA A., ALIMON A.R., AZHAR K., NOOR H.M. SAMSUDIN A.A. 2014. *Improving nutritional values of palm kernel cake (PKC) as poultry feeds. A Review*. Malaysian Journal of Animal Science, 17(1): 1–18.

SOBOTKA W., DENABURSKI J., JABŁOŃSKA A. 2011. *The effect of grain species and feed enzymes on production results, salughter value and meat quality in pigs.* Polish Journal of Natural Sciences, 26 (1): 37–46.

WENK C. 2001. *The role of dietary fibre in thedigestive physiology of pig.* Nimal Sience and Technology, 90: 21–33.

WING-KEONG N., KAI-KAI C. 2002. *The nutritive value of palm kernel meal and the effect of enzyme supplementation in practical diets for red hybrid tilapia* (Oreochromis ssp.). Asian Fisheries Science, 15: 167–176.