UNIVERSITI PUTRA MALAYSIA

EFFECT OF FEEDING PALM KERNEL CAKE FERMENTED BY FIBER DEGRADING BACTERIA ON PERFORMANCE OF BROILER CHICKEN

MOHAMED M IDRIS ALSHELMANI

FP 2015 78

EFFECT OF FEEDING PALM KERNEL CAKE FERMENTED BY FIBER DEGRADING BACTERIA ON PERFORMANCE OF BROILER CHICKEN

By

MOHAMED M IDRIS ALSHELMANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

February 2015

DEDICATION

I would like to dedicate this work to those who taught, motivated and helped me throughout my study. This work is also dedicated to my lovely mother, my dearest wife and my cute children as well as my brothers and sisters.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of requirement for the Degree of Doctor of Philosophy

EFFECT OF FEEDING PALM KERNEL CAKE FERMENTED BY FIBER DEGRADING BACTERIA ON PERFORMANCE OF BROILER CHICKEN

By

MOHAMED M IDRIS ALSHELMANI

February 2015

Chairman: Professor Loh Teck Chwen, PhD
Faculty: Agriculture

Malaysia has an abundant amount of palm kernel cake (PKC), which is considered to be an agro-industrial waste after the extraction process of oil from palm fruits. The challenge of using the PKC in the poultry diet is the presence of the high levels of fibers. were conducted to investigate the effect of palm kernel cake fermented Based on the limitation and importance of using the PKC in broiler diets, it appears to be necessary to improve the nutritive value of this by-product by solid state fermentation (SSF) using fiber degrading bacteria. Therefore, four experiments by cellulolytic bacteria (FPKC) on the performance of broiler. The objectives of the first two experiments were to characterize the cellulolytic bacteria in terms of their properties of producing cellulolytic enzymes; in addition, to improve the nutritive value of the PKC via SSF. In addition, a digestibility trial was conducted to investigate the effect of FPKC on crude protein (CP) and amino acids (AA) digestibility on broiler chickens. The fourth experiment was carried out to study the effect of FPKC on broiler growth performance, carcass and meat quality, nutrient digestibility, villi height, gut microflora and blood biochemistry. In the first experiment, nine cellulolytic bacteria were characterized in different substrates; carboxymethyl cellulose (CMC) or xylan from birchwood or locus bean gum (LBG) galactomannan. Results showed that *Bacillus amyloliquefaciens* DSMZ 1067, *Bacillus megaterium* ATCC 9885, *Paenibacillus curdlanolyticus* DSMZ 10248, and *Paenibacillus polymyxa* ATCC 842 produced higher enzymes activities compared to the other bacterial cultures grown in different substrates. In the

second experiment, the PKC was undergone SSF by the four cellulolytic bacteria mentioned earlier. The findings observed that bacterial cultures produced high enzymes activities at the 4th day of SSF, and decreased to zero at the 8th day of SSF. Moreover, the fiber contents were significantly decreased ($P< 0.05$) and the reducing sugars were significantly increased ($P< 0.05$) in FPKC compared with untreated PKC. In the third experiment, a total of 24 broiler chickens were randomly distributed into three treatments: untreated PKC, FPKCa by *P. polymyxa* ATCC 842 and FPKCb by *P. curdlanolyticus* DSMZ 10248. The findings showed that of CP was increased from 16.47% in the untreated PKC to 16.68% and 16.80% in FPKCa and FPKCb, respectively. In addition, the apparent ileal digestibility (AID) of CP and glutamate were significantly ($P< 0.05$) increased in FPKCa compared to the untreated PKC. The rest of AA digestibility were increased in FPKC but not significantly different ($P> 0.05$). In the fourth experiment, a total of 245 one-day-old broiler chicks were randomly distributed to seven dietary treatments containing 0, 5, 10 and 15% PKC and 5, 10 15% FPKC by *P. polymyxa* ATCC 842. The results showed that the addition of 10 or 15% PKC in broiler diets led to a significant ($P<0.05$) decrease in the growth performance and nutrient digestibility. However, it was significantly ($P<0.05$) improved in groups of chickens fed with 10 or 15% FPKC compared with those fed with 10 or 15% PKC. The relative weight of the gizzard was significantly ($P< 0.05$) higher for the broiler group fed with 15% PKC compared to those birds fed with the negative control or FPKC at three weeks of age. No significant ($P> 0.05$) differences were observed between the dietary treatments in terms of meat quality, blood biochemistry, villi height and internal organs. Nevertheless, gut microflora were significantly improved ($P< 0.05$) in birds fed with 15% FPKC compared to the other dietary treatments. In conclusion, PKC fermented by *P. polymyxa* ATCC 842 could be fed to broiler chickens up to 15% in their rations without any adverse effects on their growth performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

KESAN PEMAKANAN ISIRUNG KELAPA SAWIT TERTAPAI OLEH BAKTERIA PENGURAI SERAT TERHADAP PRESTASI AYAM PEDAGING

Oleh

MOHAMED M IDRIS ALSHELMANI

Februari 2015

Pengerusi: Professor Loh Teck Chwen, PhD
Fakulti: Pertanian

Malaysia mempunyai sejumlah besar isirung kelapa sawit (IKS) yang dikategorikan sebagai sisa buangan industri sejurus selesai proses pengekstrakan minyak sawit. Penghalang penggunaan IKS dalam diet ternakan ialah tahap seratnya yang tinggi. Berdasarkan kepada keterbatasan dari segi pengambilan dan kepentingan IKS dalam diet ayam pedaging, maka adalah wajar untuk meningkatkan kandungan nutrisi pada produk sampingan fermentasi pepejal ini dengan menggunakan bakteria pengurai serat. Untuk tujuan tersebut, empat eksperimen telah dijalankan untuk mengenal pasti kesan IKS tertapai (fermented) oleh bakteria cellulolytic ke atas prestasi ayam pedaging. Objektif eksperimen pertama dan kedua adalah untuk mengenal pasti sifat atau ciri-ciri pada bakteria cellulolytic dalam penghasilan enzim. Matlamat lain adalah untuk menambah baik nilai nutrisi pada IKS melalui kaedah fermentasi pepejal. Ujian ketercernaan turut dijalankan bagi mengkaji kesan IKS tertapai terhadap protein kasar (crude protein) dan ketercernaan asid amino terhadap ayam pedaging. Eksperimen keempat dijalankan untuk menganalisis kesan IKS tertapai terhadap prestasi pertumbuhan ayam pedaging, karkas dan kualiti daging, ketercernaan nutrien, ketinggian vilus, mikroflora usus dan biokimia darah. Dalam eksperimen yang pertama, Sembilan bakteria cellulolytic telah dikelaskan kepada beberapa substrat yang berbeza, iaitu carboxymethyl cellulose (CMC) atau xylan daripada birchwood atau locus bean gum (LBG) galactomannan. Dapatan menunjukkan bahawa *Bacillus amyloliquefaciens* DSMZ 1067, *Bacillus megaterium* ATCC 9885, *Paenibacillus curdlanolyticus* DSMZ 10248, dan *Paenibacillus polymyxa* ATCC 842

menghasilkan aktiviti enzim yang lebih tinggi daripada kultur bakteria daripada substrat yang lain. Dalam eksperimen yang kedua, IKS telah melalui proses fermentasi pepejal oleh bakteria cellulolytic. Penemuan daripada eksperimen ini menunjukkan bahawa kultur bakteria menghasilkan aktiviti enzim yang tinggi pada hari keempat proses fermentasi dan menurun pada nilai sifar pada hari kelapan. Tambahan pula, nilai kandungan serat menurun ($P< 0.05$) dan nilai gula meningkat ($P< 0.05$) dalam IKS tertapai berbanding IKS yang tidak dirawat. Dalam eksperimen ketiga, sebanyak 24 ekor ayam pedaging dibahagikan kepada tiga rawatan, iaitu IKS tidak dirawat, IKSa oleh *P. polymyxa* ATCC 842 dan IKSb oleh *P. curdlanolyticus* DSMZ 10248. Hasilnya, protein kasar meningkat daripada 16.47% kepada 16.68% dalam IKS tidak dirawat dan meningkat kepada 16.80% dalam IKSa dan IKSb. Nilai ketercernaan ileum semu (apparent ileal digestibility) pada protein kasar dan glutamate bertambah ($P< 0.05$) dalam IKS tanpa perbezaan yang ketara ($P> 0.05$). Dalam eksperimen keempat, sebanyak 245 ekor ayam pedaging berusia satu hari dibahagikan secara rawak kepada tujuh rawatan diet yang mengandungi 0, 5, 10 dan 15% IKS dan 5, 10 dan 10% IKS tertapai oleh *P. polymyxa* ATCC 842. Dapatan menunjukkan bahawa penambahan 10 atau 15% IKS ke dalam diet ayam pedaging menurunkan ($P<0.05$) prestasi pertumbuhan dan ketercernaan nutrien. Walau bagaimanapun, nilai ini diperbaik ($P<0.05$) dalam kumpulan ayam yang menerima 10 atau 15% IKS tertapai. Berat relatif hempedal ($P<0.05$) adalah lebih tinggi pada ayam pedaging yang menerima 15% IKS berbanding kumpulan yang mengambil IKS tertapai atau pemakanan tidak terkawal pada usia tiga minggu. Tidak terdapat perbezaan ketara ($P> 0.05$) dikenal pasti pada rawatan pemakanan dari segi kualiti daging, biokimia darah, ketinggian vilus dan organ dalaman, melainkan mikroflora usus yang mengalami perubahan ketara ($P<0.05$) pada ayam yang menerima 15% IKS tertapai. Kesimpulannya, IKS yang difermentasi oleh *P. polymyxa* ATCC 842 boleh diberikan kepada ayam pedaging sehingga kadar nisbah 15% tanpa sebarang kesan sampingan terhadap prestasi pertumbuhannya.

ACKNOWLEDGEMENTS

I would like to express my sincerest thanks and gratitude to my supervisor Professor Dr. Loh Teck Chwen for his advice, motivation, patience and support throughout my PhD study.

I would also like to express my thanks to my co-supervisors Dr. Awis Qurni Sazili and Dr. Lau Wei Hong for their advices and recommendations.

I would like also to express my special gratitude to the Associate Professor Dr. Foo Hooi Ling at the Department of Bioprocess and Technology, Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia (UPM) for her guidance, support, positive criticisms and encouragement throughout my study. The appreciation is also extended to her postgraduate students for their assistance during my microbiology work in their lab.

My appreciation is also extended to my colleagues in the Department of Animal Science and Institute of Tropical Agriculture for their assistance whether in the labs or in the poultry unit at UPM. My thanks are also extended to the lab technicians in the Department of Animal Science. My thankful also extended to Mrs Nor Afilah for translating the abstract to Bahasa Melayu.

I would like also to express my gratitude to my friend Dr. Abdelrahim Abubakr for his assistance and advices throughout my study.

I am also thankful to my colleagues; Dr Ahmed Abe Wadi Aljuobori and Elmutaz Atta Awad for their assistance and motivation.

Last but not least, I would like to express my thanks to my wife and children for their patience, sacrifice and encouragement during my life and throughout my study.

I certify that a Thesis Examination Committee has met on 12 February 2015 to conduct the final examination of Mohamed M. Idris Ali Alshelmani on his thesis entitled "Effect of Feeding Palm Kernel Cake Fermented by Fiber Degrading Bacteria on Performance of Broiler Chicken" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

Members of the Examination Committee were as follows:

Halimatun Yaakub, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Abdul Razak Bin Alimon, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Wan Zuhainis Binti Saad, PhD
Lecturer
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Internal Examiner)

Ashok Kumar Pattanaik, PhD
Professor
Clinical and Pet Nutrition, Division of Animal Nutrition
Indian Veterinary Research Institute
India
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia
Date: 15 April 2015

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of philosophy. The members of the Supervisory Committee were as follows:

Loh Teck Chwen, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Awis Qurni Sazili, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Lau Wei Hong, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia
Date: 14 May 2015

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: _____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____

Name of Chairman of Supervisory Committee: _____

Signature: _____

Name of Member of Supervisory Committee: _____

Signature: _____

Name of Member of Supervisory Committee: _____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PKC	Palm kernel cake
FPKC	Fermented palm kernel cake
ATCC	American Type Culture Collection
DSMZ	Leibniz Institute DSMZ-German Collection of Microorganisms and Cell Culture
SSF	Solid state fermentation
CF	Crude fiber
DM	Dry matter
NDF	Neutral detergent fiber
ADF	Acid detergent fiber
ADL	Acid detergent lignin
EE	Ether extract
CP	Crude protein
NFE	Nitrogen free extract
GE	Gross energy
ME	Metabolizable energy
AME	Apparent metabolizable energy
TMEn	True metabolizable energy nitrogen corrected
NSPs	Non-starch polysaccharides
PKM	Palm kernel meal
MOS	Mannanoligosaccharide
FAO	Food and Agriculture Organization
Glu	Glucose
Gal	Galactose
Man	Mannan
LAB	Lactic acid bacteria
ENT	Enterobacteriaceae
CFU	Colony forming unit
CMC	Carboxymethyl cellulose
LBG	Locust bean gum
RTU	Ready to use
DNS	3,5 dinitrocalysilic acid
dH_2O	Distilled water
OD	Optical density
BSA	Bovine serum albumin
CRD	Complete randomized design
GLM	General linear model
SAS	Statistical analysis system
ANOVA	Analysis of variance
CTAB	Acetyl methyl ammonium bromide
OPA	O-phthalaldehyde reagent
FMOC	Fluorenyl methyl chloroformate reagent
GIT	Gastrointestinal tract
HPLC	High performance liquid chromatography
BW	Body weight

BWG	Body weight gain
FI	Feed intake
FCR	Feed conversion ratio
CIE	Commission on illumination
WHC	Water holding capacity
EDTA	Ethelenedimethyl tetra acetic acid
BCG	Bromcresol green
LPL	Lipoprotein lipase
TAG	Triacylglycerol
MRS	De Man ROGOSA and SHAPE
H_2SO_4	Sulforic acid
HBr	Hydrogen bromide
NaOH	Sodium hydroxide
Na2HPO4	Di sodium hydrogen phosphate anhydrous
NaH_2PO_4	Sodium dihydrogen phosphate
Kg	Kilo gram
g	Gram
M	Molar
N	Normal
H_2O_2	Hydrogen peroxide
L	Liter
ml	Milli liter
µl	Micro liter
AID	Apparent ileal digestibility
ISR	Internal standard ratio
SDW	Sample dry weight
VFA	Volatile fatty acids

CHAPTER I

GENERAL INTRODUCTION

The global consumption of poultry products such as meat or eggs, nowadays, is showing on increased trend in the developing countries. On the other hand, the global demand for the main poultry feedstuffs will be increased, especially the protein and energy resources such as soybean meal and yellow corn, respectively. Therefore, the global price of these feed stuffs will be increased. Thus, the cost of poultry diets will definitely be increased as a result of the global demand. The availability of feedstuffs for poultry nutrition nowadays is becoming more competitive. The world's population is expected to increase to 9.1 billion in 2050 (FAO, 2009). Therefore, for human consumption demands for poultry products such as meat and eggs will be increased. In addition, there is an increasing trend to produce biofuel from feedstuffs, especially corn, to meet the deficiency of energy sources all over the world. Thus, the food security, especially in the developing countries will be threatened.

Currently, efforts are being made world over to use alternative sources of protein and energy to be substituted for soybean meal and yellow corn in monogastric animals such as poultry and swine. It is known that some developing countries produce a huge amount of alternative feedstuffs, considered as agro waste by–products such as wheat bran, rice bran, cotton seed meal, copra meal and palm kernel cake. However, many of these agro waste by–products are featuring on presence of non-starch polysaccharides (NSPs) such as xylan and mannan as well as anti-nutritional factors.

The NSPs found to be the main reason for increasing the viscosity in the small intestine of the birds, and hence lead to increased moisture content of the excreta. Thus, the productivity and health status of the chickens could be affected. Therefore, the inclusion of these agro waste by–products in poultry feed are limited.

The global production of palm kernel cake (PKC) has been increased in several tropical countries. It is known that Malaysia is one of the largest worldwide producers of palm oil, and therefore, it produces a huge amount of PKC which is considered as an agro waste by–product.

PKC is the by-product of oil extraction from palm fruits, and it has been used in poultry diets as an alternative of soybean meal. However, the use of PKC is limited in poultry nutrition because of its high content of fibers, coarse texture and gritty appearance (McDonald *et al.,* 1995; O'Mara *et al.,* 1999; Sundu and Dingle, 2002). This is considered as a big problem facing the nutritionists, and has restricted the use of PKC for manipulation of feed formulation. Hence,

there is a need to use other techniques to improve the quality of PKC either with supplementation of exogenous enzymes, or through fermentation of the PKC by cellulolytic microorganisms expecting that these treatments would improve the digestibility and nutritional value. Not only does the fermentation of PKC by microorganisms lead to decrease the crude fiber content, but it would also increase the crude protein as well as amino acids.

The PKC itself may be beneficial to poultry health and production as this by–product contains mannanoligosaccharide (MOS) (Anaeto *et al.,* 2009). The MOS is considered to be a prebiotic that can reduce the pathogenic bacteria as well as increase the health-positive bacteria in the hind gut of the broiler chickens.

Recently, more emphasis is being given to use cellulolytic microorganisms such as fungus or bacteria to produce fermented PKC rather than the supplementation of exogenous enzymes in poultry diets. This technique allows the nutritionists to increase the PKC inclusion levels in poultry diets to improve their performance, and decrease the cost of diets as a result of substitute PKC for soybean meal and yellow corn. This technique is known as solid state (substrate) fermentation (SSF) which enables the cellulolytic microorganisms via their enzymes to breakdown the β–glycosidic bonds that link the cellulose, xylan and mannan in the PKC.

It is known that nutrition account for about 60% to 70% of the total cost in poultry production. The nutritionists attempt to substitute local feedstuffs for soybean meal which is considered to be the main source of protein in feed formulation. Nevertheless, some of local feedstuffs are not acceptable for monogastric animals and therefore used in small proportions in their diets. Malaysia produces abundant amount of PKC, and it could constitute an important by-product feed if it could be successfully exploited by supplementation of exogenous enzymes, or inoculation with cellulolytic microorganisms such as fungus or bacteria to modify the high levels of fibers as well as improving the crude protein. However, the use of fungus in SSF could produce mycotoxins during the fermentation process. Therefore, using cellulolytic bacteria might be more effective to avoid the production of mycotoxins during the fermentation of the PKC.

Objectives

The main objective of this research was to study the effect of feeding fermented PKC (FPKC) produced using cellulolytic bacteria on the performance of broiler chickens.

The specific objectives of this study were:

- To characterize the cellulolytic bacteria on different substrates, and to determine the optimum PKC - moisture ratio during solid state fermentation (SSF).

- To improve the nutritive quality to the PKC by SSF using cellulolytic bacteria.

- To study the effect of FPKC on crude protein and amino acid digestibility.

- To investigate the effect of FPKC on nutrient digestibility, broiler performance, meat quality, abdominal fat, internal organs, blood biochemistry, gut microflora and villi height and crypt depth.

Malaysia has an abundant amount of PKC, which is considered to be an agro-industrial waste after the extraction process of oil from palm fruits. The challenge of using the PKC in the poultry diet is the presence of the high levels of fibers. Based on the limitation and importance of using the PKC in broiler diets, it appears to be necessary to improve the nutritive value of this by-product. Several attempts have been made to degrade the PKC by using solid state fermentation (SSF) in order to improve the nutritive quality.

REFERENCES

´Alvarez-Cervantes, J., Hern´andez-Dom´ınguez, E. M., Arana-Cuenca, A., G.D´ıaz-God´ınez and Y.Mercado-Flores. (2013). Purification and characterization of xylanase SRXL1 from sporisorium reilianum grown in submerged and solid-state fermentation. *BioResources*, **8**, 5309-5318.

Adrizal, A., Yusrizal, Y., Fakhri, S., Haris, W., Ali, E. and Angel, C. R. (2011). Feeding native laying hens diets containing palm kernel meal with or without enzyme supplementations: 1. Feed conversion ratio and egg production. *The Journal of Applied Poultry Research*, **20** (1), 40-49.

Ahmed, A., Zulkifli, I., Farjam, A. S., Abdullah, N., Liang, J. B. and Awad, E. A. (2014). Effect of solid state fermentation on nutrient content and ileal amino acids digestibility of canola meal in broiler chickens. *Italian Journal of Animal Science,* **13** (2), 410 - 414.

Alexander, B. and Priest, F. G. (1989). *Bacillus glucanolyticus*, a new species that degrades a variety of β-glucans. *International Journal of Systematic Bacteriology*, **39** (2), 112-115.

Alimon, A. R. (2004). The nutritive value of palm kernel cake for animal feed. *Palm Oil Development*, **40** (1), 12 - 14.

Alvarado, C. Z., Richards, M. P., O'Keefe, S. F. and Wang, H. (2007). The effect of blood removal on oxidation and shelf life of broiler breast meat. *Poultry Science*, **86** (1), 156-161.

Alvarez, V. M., Von Der Weid, I., Seldin, L. and Santos, A. L. S. (2006). Influence of growth conditions on the production of extracellular proteolytic enzymes in *Paenibacillus peoriae* NRRL BD-62 and *Paenibacillus polymyxa* SCE2. *Letters in Applied Microbiology*, **43** (6), 625-630.

AMSA. (2012). AMSA Meat Color Measurement Guidelines. USA: American Meat Science Association, Illinois.

Anaeto, M., Chioma, G. O. and Omosebi, D. J. (2009). Palm kernel cake as substitute for maize in broiler finisher diet. *International Journal of Poultry Science*, **8** (12), 1206-1208.

Annison, G. and Choct, M. (1991). Anti-nutritive activities of cereal non-starch polysaccharides in broiler diets and strategies minimizing their effects. *World's Poultry Science Journal*, **47** (3), 232-242.

Anuraj, N. S., Ahmed, S., Yadav, M., Singh, S., A, M. A., Maynal, M. and Pisal, U. (2012). Identification and characterization of neutral protease

producing *Paenibacillus polymyxa* species EMBS024 by 16S rRNA gene sequence. *International Journal of Microbiology Research*, **4** (5), 236-239.

Ao, X., Zhou, T. X., Meng, Q. W., Lee, J. H., Jang, H. D., Cho, J. H. and Kim, I. H. (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. (1995). *Association of official analytical chemists*. *16 ed*. Association of official analytical chemists, Washington, DC.

Araujo, A. and Ward, O. P. (1990). Extracellular mannanases and galactanases from selected fungi. *Journal of Industrial Microbiology and Biotechnology*, **6** (3), 171-178.

Archana, A. and Satyanarayana, T. (1997). Xylanase production by thermophilic *Bacillus licheniformis* A99 in solid-state fermentation. *Enzyme and Microbial Technology*, **21** (1), 12-17.

Aya, V., Ayanwale, B., Ijaiya, A. and Aremu, A. (2013). Performance and nutrient digestibility in broiler chicks as influenced by multienzyme addition to starter diets containing palm kernel meal. *Biotechnology in Animal Husbandry*, **29** (1), 93-104.

Bailey, M. J., Biely, P. and Poutanen, K. (1992). Interlaboratory testing of methods for assay of xylanase activity. *Journal of Biotechnology*, **23** (3), 257-270.

Battan, B., Sharma, J. and Kuhad, R. (2006). High-level xylanase production by alkaliphilic *Bacillus pumilus* ASH under solid-state fermentation. *World Journal of Microbiology and Biotechnology*, **22** (12), 1281-1287.

Baurhoo, B., Letellier, A., Zhao, X. and Ruiz-Feria, C. A. (2007). Cecal populations of *Lactobacilli* and *Bifidobacteria* and *Escherichia coli* populations after in vivo *Escherichia coli* challenge in birds fed diets with purified lignin or mannanoligosaccharides. *Poultry Science*, **86**, 2509–2516.

Bello, K. M., Oyawoye, E. O., Bogoro, S. E. and Dass, U. D. (2011a). Performance of broilers fed varying levels of palm kernel cake. *International Journal of Poultry Science,* **10** (4), 290-294.

Bello, K. M., Oyawoye, E. O. and Bogoro, S. E. (2011b). Response of cockerels to graded levels of local and industrially processed palm kernel meal (Elaise guineasis). *African Journal of Agricultural Research,* **6** (27), 5934-5939.

Bello, M. K., Oyawoye, O. E. and Bogoro, E. S. (2012). Performance, carcass characteristics and blood composition of broilers fed varying levels of palm kernel meal supplemented with different Levels of fishmeal. *International Journal of Poultry Science*, **11** (1), 73-77.

Biggs, P., Parsons, C. M. and Fahey, G. C. T. (2007). The effects of several oligosaccharides on growth performance, nutrient digestibilities, and cecal microbial populations in young chicks. *Poultry Science,* **86** (11), 2327-2336.

Boateng, M., Okai, D. B., Baah, J. and Donkoh, A. (2008). Palm kernel cake extraction and utilisation in pig and poultry diets in Ghana. *Livestock Research for Rural Development,* **20** (7), 1-8.

Bradford, N. M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry,* **72** (1), 248-254.

Breccia, J. D., Faustino Sifieriz, Mario D. Baigori, Guillermo R. Castro and Hatti-Kaul', a. R. (1998). Purification and characterization of a thermostable xylanase from *Bacillus amyloliquefaciens*. *Enzyme and Microbial Technology,* **22** (1), 42-49.

Brenes, A., Marquardt, R. R., Guenter, W. and Viveros, A. (2002). Effect of enzyme addition on the performance and gastrointestinal tract size of chicks fed lupin seed and their fractions. *Poultry Science*, **81** (5), 670-678.

Cavitt, L. C., Youm, G. W., Meullenet, J. F., Owens, C. M. and Xiong, R. (2004). Prediction of Poultry Meat Tenderness Using Razor Blade Shear, Allo-Kramer Shear, and Sarcomere Length. *Journal of Food Science*, **69** (1), 11-15.

Chen, H., Mao, X. B., Che, L. Q., Yu, B., He, J., Yu, J., Han, G. Q., Huang, Z. Q., Zheng, P. and Chen, D. W. (2014). Impact of fiber types on gut microbiota, gut environment and gut function in fattening pigs. *Animal Feed Science and Technology*, **195**, 101-111.

Chen, W. L., Liang, J. B., Jahromi, M. F., Ho, Y. W. and Abdullah, N. (2013). Optimization of multi-enzyme production by fungi isolated from palm kernel expeller using response surface methodology. *BioResources*, **8** (3), 3844-3857.

Chinajariyawong, C. and Muangkeow, N. (2011). Carcass yield and visceral organs of broiler chickens fed palm kernel meal or *Aspergillus wentii* TISTR 3075 fermented palm kernel meal. *Walailak Journal of Science and Technology,* **8** (2), 175 - 185.

Cho, K. M., Math, R. K., Hong, S. Y., Asraful Islam, S. M., Kim, J. O., Hong, S. J., Kim, H. and Yun, H. D. (2008). Changes in the activity of the

multifunctional beta-glycosyl hydrolase (Cel44C-Man26A) from *Paenibacillus polymyxa* by removal of the C-terminal region to minimum size. *Biotechnology Letters*, **30** (6), 1061-1068.

Choe, D. W., Loh, T. C., Foo, H. L., Hair-Bejo, M. and Awis, Q. S. (2012). Egg production, faecal pH and microbial population, small intestine morphology, and plasma and yolk cholesterol in laying hens given liquid metabolites produced by *Lactobacillus plantarum* strains. *British Poultry Science*, **53** (1), 106-115.

Chong, C. H. (1999). *Improving utilization of poultry feedstuffs with supplemental amino acids and enzymes*. PhD Thesis, University of British Columbia. Canada.

Chong, C. H., Zulkifli, I. and Blair, R. (2008). Effects of dietary inclusion of palm kernel cake and palm oil, and enzyme supplementation on performance of laying hens. *Asian-Australian Journal Animal Science*, **21** (7), 1053 - 1058.

Dairo, F. A. S. and Fasuyi, A. O. (2008). Evaluation of fermented palm kernel meal and fermented copra meal proteins as substitute for soybean meal protein in laying hens diets *Central European Journal of Agriculture*, **9** (1), 35 - 44.

de Barros Soares, L., Assmann, F. and Záchia Ayub, M. (2003). Production of transglutaminase from *Bacillus circulans* on solid-state and submerged cultivations. *Biotechnology Letters*, **25** (23), 2029-2033.

Dégen, L., Halas, V. and Babinszky, L. (2007). Effect of dietary fibre on protein and fat digestibility and its consequences on diet formulation for growing and fattening pigs: A review. *Acta Agriculturae Scandinavica, Section A – Animal Science*, **57** (1), 1-9.

Dhawan, S. and Kaur, J. (2007). Microbial mannanases: An overview of production and applications. *Critical Reviews in Biotechnology*, **27** (4), 197-216.

El-Ghonemy, D. H. I., Thanaa, H. A. and Maysa, E. M. (2014). Optimization of culture conditions for the production of extracellular cellulases via solid state fermentation. *British Microbiology Research Journal.*, **4** (6), 698-714.

Ezema, C. and Eze, D. C. (2009). Performance and economic benefit of broilers fed palm kernel cake-based diet supplemented with probiotic. *International Journal of Poultry Science,* **8** (10), 1003-1005.

Ezieshi, E. V. and Olomu, J. M. (2004). Comparative performance of broiler chickens fed varying levels of palm kernel cake and maize offal. *Pakistan Journal of Nutrition,* **3** (4), 254-257.

Ezieshi, E. V. and Olomu, J. M. (2007). Nutritional evaluation of palm kernel meal types: 1. Proximate composition and metabolizable energy values. *African Journal of Biotechnology,* **6** (21), 2484-2486.

Fan, S. P., Jiang, L. Q., Chia, C. H., Fang, Z., Zakaria, S. and Chee, K. L. (2014). High yield production of sugars from deproteinated palm kernel cake under microwave irradiation via dilute sulfuric acid hydrolysis. *Bioresource Technology*, **153**, 69-78.

FAO. (2009). How to feed the world in 2050. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy

Fasuyi, A., Abiodun, S. and Akomolafe, O. (2014). Bioconversion and enzymes fortification of palm kernel meal as protein supplement in broiler rations. *American Journal of Experimental Agriculture*, **4** (7), 767-784.

Fernandez, F., Hinton, M. and Gils, B. V. (2002). Dietary mannan-oligosaccharides and their effect on chicken caecal microflora in relation to Salmonella Enteritidis colonization. *Avian Pathology*, **31** (1), 49-58.

Fernandez, F., Hinton, M. and Van Gils, B. (2000). Evaluation of the effect of mannan-oligosaccharides on the competitive exclusion of Salmonella Enteritidis colonization in broiler chicks. *Avian Pathology*, **29** (6), 575-581.

Fernandez, X., Forslid, A. and Tornberg, E. (1994). The effect of high post-mortem temperature on the development of pale, soft and exudative pork: Interaction with ultimate pH. *Meat Science*, **37** (1), 133-147.

Fletcher, D. L. (1999). Broiler breast meat color variation, pH, and texture. *Poultry Science*, **78** (9), 1323-1327.

Foo, H. L., Loh, T. C., Lim, H. A., Shukriyah, M. H., Kufli, C. N. and Law, F. L. (2003). Effects of fermented fruits on growth performance, shedding of enterobacteriaceae and Lactic acid bacteria and plasma cholesterol in rats. *Pakistan Journal of Nutrition*, **2** (4), 228-233.

Francech, M. and Brufau, J. (2004). Nutritional factors affecting excreta/litter moisture and quality. *World' Poultry Science Journal*, **60** (1), 64 - 75.

Gangadharan, D., Sivaramakrishnan, S., Nampoothiri, K. M. and Pandey, A. (2006). Solid culturing of *Bacillus amyloliquefaciens* for alpha amylase production. *Food Technology and Biotechnology*, **44** (2), 269–274.

Gao, F., Jiang, Y., Zhou, G. H. and Han, Z. K. (2008). The effects of xylanase supplementation on performance, characteristics of the gastrointestinal tract, blood parameters and gut microflora in broilers fed on wheat-based diets. *Animal Feed Science and Technology*, **142** (1–2), 173-184.

Gautam, S. P., Bundela, P. S., Pandey, A. K., A.M.K, J. and Sarsaiya, S. (2010). Optimization of the medium for the production of cellulase by the *Trichoderma viride* using submerged fermentation. *International Journal of Environmental Sciences*, **1** (4), 656-665.

Gessesse, A. and Mamo, G. (1999). High-level xylanase production by an alkaliphilic Bacillus sp. by using solid-state fermentation. *Enzyme and Microbial Technology*, **25** (1–2), 68-72.

Girardin, H., Albagnac, C., Dargaignaratz, C., and Carlin, F. (2002). Antimicrobial activity of foodborne *Paenibacillus* and *Bacillus* spp. against *Clostridium botulinum*. *Journal of Food Protection*, **65** (5), 806-813.

Goering, H. K. and Van Soest, P. J. (1970). Forage fiber analysis (apparatus, reagents, prosedures and some applications). USDA. *Agricultural Handbook. No 379*

Graminha, E. B. N., Gonçalves, A. Z. L., Pirota, R. D. P. B., Balsalobre, M. A. A., Da Silva, R. and Gomes, E. (2008). Enzyme production by solid-state fermentation: Application to animal nutrition. *Animal Feed Science and Technology*, **144** (1–2), 1-22.

Gupta, U. and Kar, R. (2008). Optimization and scale up of cellulase free endo-xylanase production by solid state fermentation on corn cob and by immobilized cells of a thermolerant bacterial isolates. *Jordan Journal of Biological Sciences*, **1** (3), 129-134.

Honikel, K. O. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Science*, **49** (4), 447-457.

Hunt, M. C. (1980). Meat color measurements. *Proceedings Annual Reciprocal Meat Conference*.

Igri, O. B. and Ausaji, A. A. (2006). Carcass characteristics and meat quality of broilers fed periwinkle flesh (Pachymelania aurita), palm kernel cake and oil-based rations. *Journal of the Science of Food and Agriculture*, **86** (3), 362-366.

Iluyemi, F. B., Hanafi, M. M., Radziah, O. and Kamarudin, M. S. (2006). Fungal solid state culture of palm kernel cake. *Bioresource Technology,* **97** (3), 477-482.

Iyayi, E. A. and Davies, B. I. (2005). Effect of enzyme supplementation of palm kernel meal and brewer's dried grain on the performance of broilers. *International Journal of Poultry Science,* **4** (2), 76-80.

Jones, A., Reed, R. and Weyers, J. (2007). *Practical skills in Biology*. 4th edition. Pearson Eduation.

Jones, S. M., Van Dyk, J. S. and Pletschke, B. L. (2012). *Bacillus subtilis* SJ01 produces hemicellulose degrading multi-enzyme complexes. *Bioresources*, **7** (1), 1294-1309.

Jung, H. K., Hong, J. H., Park, S., Chun, Park, B. K., Nam, D. H. and Kim, H. (2007). Production and physicochemical characterization of β-glucan produced by *Paenibacillus polymyxa* JB115. *Biotechnology and Bioprocess Engineering,* **12**, 713-719.

Kalmendal, R., Elwinger, K., Holm, L. and Tauson, R. (2011). High-fibre sunflower cake affects small intestinal digestion and health in broiler chickens. *British Poultry Science*, **52** (1), 86-96.

Khanna, S. and Gauri. (1993). Regulation, purification, and properties of xylanase from *Cellulomonas fimi*. *Enzyme and Microbial Technology,* **15** (11), 990 - 995.

Kheng, P. P. and Omar, I. C. (2005). Xylanase production by a local, fungal isolate, *Aspergillus niger* USM A1 via olid state fermentation using palm kernel cake (PKC) as substrate. *Songklanakarin Journal of Science and Technology,* **27**, 325-336.

Khin, H. S. (2004). *Evaluation of solid state fermetation by Aspergillus niger to improve the nutritive value of palm kernel cake for broilers*. PhD Thesis, Universiti Putra Malaysia. Malaysia

Kocher, A., Choct, M., Porter, M. D. and Broz, J. (2002). Effects of feed enzymes on nutritive value of soyabean meal fed to broilers. *British Poultry Science*, **43** (1), 54-63.

Krishna, C. (1999). Production of bacterial cellulases by solid state bioprocessing of banana wastes. *Bioresource Technology*, **69** (3), 231-239.

Lan, Y., Verstegen, M., Tamminga, S. and B.A, W. (2005). The role of the commensal gut microbial community in broiler chickens. *World's Poultry Science Journal,* **61** (1), 95-104.

Landman, O. E. (1957). Properties and induction of β-galactosidase in *Bacillus megaterium*. *Biochimica et Biophysica Acta*, **23**, 558-569.

Lateef, A., Oloke, J. K., Gueguim Kana, E. B., Oyeniyi, S. O., Onifade, O. R., Oyeleye, A. O., Oladosu, O. C. and Oyelami, A. O. (2008). Improving the quality of agro-wastes by solid-state fermentation: enhanced antioxidant activities and nutritional qualities. *World Journal of Microbiology and Biotechnology*, **24** (10), 2369-2374.

Lawal, T. E., Iyayi, E. A., Adeniyi, B. A. and Adaramoye, O. A. (2010). Biodegradation of palm kernel cake with multienzyme complexes from

fungi and its feeding value for broiler. *International Journal of Poultry Science*, **9** (7), 695-701

Lee, K. W., Lee, S. K. and Lee, B. D. (2006). *Aspergillus oryzae* as probiotic in poultry - A review. *International Jounal of Poultry Science*, **5** (1), 1-3.

Lilly, R. A. (2010). *The effect of diatary amino acid density in broiler on carcass characteristics and meat quality*. Master Thesis, Mississippi State University. USA.

Liu, H. W. and Zhou, D. W. (2013). Influence of pasture intake on meat quality, lipid oxidation, and fatty acid composition of geese. *Journal of Animal Science*, **91** (2), 764-771.

Loh, T., Choe, D., Foo, H., Sazili, A. and Bejo, M. (2014). Effects of feeding different postbiotic metabolite combinations produced by Lactobacillus plantarum strains on egg quality and production performance, faecal parameters and plasma cholesterol in laying hens. *BMC Veterinary Research*, **10** (1), 149.

Loh, T., Chong, S., Foo, H. and Law, F. (2009). Effects on growth performance, faecal microflora and plasma cholesterol after supplementation of spray-dried metabolite to postweaning rats. *Czech Journal Animal Science*, **54** (1), 10-16.

Loh, T. C., Foo, H. L., Tan , B. K. and Jelan, Z. A. (2002). Effects of palm kernel cake on performance and blood lipids in rats. *Asian-Australian Journal of Animal Science*, **15** (8), 1165-1169.

Loh, T. C., Thanh, N. T., Feng, C. X. and Foo, H. L. (2008). Growth performance of broilers fed with different levels of palm kernel meal supplemented with mannanase. *29th Malaysian Society of Animal Science (MSAP),25-27 May.2008.*, Penang.

Lonsane, B. K., Saucedo-Castaneda, G., Raimbault, M., Roussos, S., Viniegra-Gonzalez, G., Ghildyal, N. P., Ramakrishna, M. and Krishnaiah, M. M. (1992). Scale-up strategies for solid state fermentation systems. *Process Biochemistry*, **27** (5), 259-273.

Ma, M., Wang, C., Ding, Y., Li, L., Shen, D., Jiang, X., Guan, D., Cao, F., Chen, H., Feng, R., Wang, X., Ge, Y., Yao, L., Bing, X., Yang, X., Li, J. and Du, B. (2011). Complete genome sequence of *Paenibacillus polymyxa* SC2, a strain of plant growth-promoting rhizobacterium with broad-spectrum antimicrobial activity. *Journal of Bacteriology*, **193** (1), 311-312.

Mabrouk, M. E. M. and El Ahwany, A. M. D. (2008). Production of β-mannanase by Bacillus amylolequifaciens 10A1 cultured on potato peels. *African Journal of Biotechnology*, **7** (8), 1123 - 1128.

Mardhati, M., Wong, H. K. and Noraini, S. (2011). Growth performance and carcass quality of broilers fed with palm kernel meal-based rations. *Journal of Tropical Agriculture and Food Science,* **39** (2), 157-166.

Marini, A. M., Daud, M. J., Noraini, S., Jame'ah, H. and Azahan, E. A. E. (2005). Performance of locally isolated microorganism in degrading palm kernel cake (PKC) fiber and improving the nutritional value of fermented PKC. *Journal of Tropical Agriculture and Food Science*, **33** (2), 311-319.

Mateos, G. G., Jiménez-Moreno, E., Serrano, M. P. and Lázaro, R. P. (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. *The Journal of Applied Poultry Research*, **21** (1), 156-174.

McDonald, P., Edwards, R. A. and Greenhalgh, J. F. D. (1995). *Animal Nutrition*. 5th edition. Longman Scientific and Technical. Longman Singapore publishers (Pte) Ltd. Printed in Singapore.

Mehri, M., Adibmoradi, M., Samie, A. and Shivazad, M. (2010). Effects of β-mannanase on broiler performance, gut morphology and immune system. *African Journal of Biotechnology,* **9** (37), 6221-6228.

Miller, G. L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Analytical Chemistry,* **31** (3)**,** 426–428.

Mirnawati, Y. R., Marlida, Y. and Kompiang, P. (2011). Evaluation of palm kernel cake fermented by *Aspergillus niger* as substituet for soybean meal protein in the diet of broiler. *International Jounal of Poultry Science*, **10** (7), 537-541.

Moftah, B., Lah, T., Nawi, A., Kadir, M. and Aliyu-Paiko, M. (2012). Maximizing glucose production from palm kernel cake (PKC) from which residual oil was removed supercritically via solid state fermentation (SSF) method using *Trichoderma Reesi* isolate Pro-A1. In *The Internet Journal of Microbiology* Vol. 10 (1).

Mohamed, M. A., Hasssan, H. M. A. and EL-Barkouky, E. M. A. (2008). Effect of mannan oligosaccharide on performance and carcass characteristics of broiler chicks. *Journal of Agriculture and Social Sciences*, **4** (1), 13-17.

Moharrery, A. and Mohammadpour, A. (2005). Effect of diets containing different qualities of barley on growth performance and serum amylase and intestinal villus morphology. *International Journal of Poultry Science*, **4** (8), 549-556.

Mok, C. H., Lee, J. H. and Kim, B. G. (2013). Effects of exogenous phytase and β-mannanase on ileal and total tract digestibility of energy and

nutrient in palm kernel expeller-containing diets fed to growing pigs. *Animal Feed Science and Technology*, **186** (3–4), 209-213.

Montagne, L., Pluske, J. R. and Hampson, D. J. (2003). A review of interactions between dietary fibre and the intestinal mucosa, and their consequences on digestive health in young non-ruminant animals. *Animal Feed Science and Technology*, **108** (1–4), 95-117.

Moreira, L. and Filho, E. (2008). An overview of mannan structure and mannan-degrading enzyme systems. *Applied Microbiology and Biotechnology*, **79** (2), 165-178.

Muangkeow, N. and Chinajariyawong, C. (2009). Determination of true amino acid digestibility and metabolizable energy in fermented palm kernel meal with *Aspergillus wentii* TISTR 3075 for chickens. *Walailak Journal of Science and Technology,* **6** (2), 231-241.

Muangkeow, N. and Chinajariyawong, C. (2013). Diets containing fermented palm kernel meal with *Aspergillus wentii* TISTR 3075 on growth performance and nutrient digestibility of broiler chickens. *Walailak Journal of Science and Technology*, **10** (2), 131 – 147.

Mustafa, M. F., Alimon, A. R., Zahari, M. W., Idris, I. and Hair Bejo, M. (2004). Nutrient digestibility of palm kernel cake for Muscovy ducks. *Asian-Australian Journal of Animal Science,* **17**(4), 514-517.

Nguyen, T. T., Loh, T. C., Foo, H. L., Bejo, M. H. and Kasim, A. (2010). Inhibitory activity of metabolites produced by strains of *Lactobacillus plantarum* isolated from Malaysian fermented food. *International Journal of Probiotics and Prebiotics*, **5** (1), 37-44.

Niba, A. T., Beal, J. D., Kudi, A. C. and Brooks, P. H. (2009). Potential of bacterial fermentation as a biosafe method of improving feeds for pigs and poultry. *African Journal of Biotechnology,* **8** (9), 1758-1767.

Nigam, P. and Pandey, A. (2009). Solid-state fermentation technology for bioconversion of biomass and agricultural residues. Biotechnology for Agro-Industrial Residues Utilisation eds. P. Nigam and A. Pandey, Springer Netherlands, pp. 197-221.

Niladevi, K., Sukumaran, R. and Prema, P. (2007). Utilization of rice straw for laccase production by *Streptomyces psammoticus* in solid-state fermentation. *Journal of Industrial Microbiology and Biotechnology*, **34** (10), 665-674.

Nochure, S. V., Roberts, M. F. and Demain, A. I. (1993). True cellulases production by *Clostridium thermocellum* grown on different carbon sources. *Biotechnology Letters*, **15**, 641-646.

Nogi, Y., Takami, H. and Horikoshi, K. (2005). Characterization of alkaliphilic Bacillus strains used in industry: proposal of five novel species. *International Journal of Systematic and Evolutionary Microbiology*, **55** (6), 2309-2315.

Nollet, L., Huyghebaert, G. and Spring, P. (2007). Effect of dietary mannan oligosaccharide (Bio-Mos) on live performance of broiler chickens given an anticoccidial vaccine (Paracox) followed by a mild coccidial challenge. *The Journal of Applied Poultry Research*, **16** (3), 397-403.

Norsalwani, T. L. and Norulaini, N. A. (2012). Utilization of lignocellulosic wastes as a carbon source for the production of bacterial cellulases under solid state fermentation. *International Journal of Environmental Science and Development*, **3**, 136-140.

National Research Council (NRC), 1994. Nutrient Requirements of Poultry (9th Rev. Ed.). National Academy Press, Washington, DC.

O'Mara, F. P., Mulligan, F. J., Cronin, E. J., Rath, M. and Caffrey, P. J. (1999). The nutritive value of palm kernel meal measured in vivo and using rumen fluid and enzymatic techniques. *Livestock Production Science*, **60** (2–3), 305-316.

Ojewola, G. S. and Ozuo, U. K. (2006). Evaluation of palm kernel meal as substitute for soyabean meal in the diet of growing cockerels. *International Journal of Poultry Science,* **5** (5), 401-403.

Okeudo, N. J., Eboh, K. V., Izugboekwe, N. V. and Akanno, E. C. (2005). Growth rate, carcass characteristics and organoleptic quality of broiler fed graded levels of palm kernel cake. *International Journal of Poultry Science*, **4** (5), 330-333.

Okeudo, N. J., Onyike, I. L., Okoli, C. V. and Chielo, I. L. (2006). Production performance, meat quality and feed cost implications of utilizing high levels of palm kernel cake in broiler finisher diets. *International Journal of Poultry Science*, **5** (12), 1160-1163.

Okorie, K. C., Ehirim, F. N., Gabriel, O., Ikpe, J. N., Okorie, R. C. and Okoro-Ugo, C. (2011). Effect of exogenous enzyme fortified palm kernel meal on the performance, carcass quality and biochemical profile of finisher broiler. *Global Research Journal of Science*, **1**, 86-92.

Onilude, A. A. and Oso, B. A. (1999a). Effect of fungal enzyme mixture supplementation of various fibre-containing diets fed to broiler chicks 1: Performance and carcass characteristics. *World Journal of Microbiology and Biotechnology*, **15** (3), 309-314.

Onilude, A. A. and Oso, B. A. (1999b). Effect of fungal enzyme mixture supplementation of various fibre-containing diets fed to broiler chicks

2: On blood, liver and kidney total lipids, triacylglycerols and cholesterol. *World Journal of Microbiology and Biotechnology*, **15** (3), 315-320.

Onwudike, O. C. (1986a). Palm kernel meal as a feed for poultry. 1. Composition of palm kernel meal and availability of its amino acids to chicks. *Animal Feed Science and Technology*, **16** (3), 179-186.

Onwudike, O. C. (1986b). Palm kernel meal as a feed for poultry. 2. Diets containing palm kernel meal for starter and grower pullets. *Animal Feed Science and Technology*, **16** (3), 187-194.

Onwudike, O. C. (1986c). Palm kernel meal as a feed for poultry. 3. Replacement of groundnut cake by palm kernel meal in broiler diets. *Animal Feed Science and Technology*, **16** (3), 195-202.

Onwudike, O. C. (1988). Palm kernel meal as a feed for poultry. 4. Use of palm kernel meal by laying birds. *Animal Feed Science and Technology*, **20** (4), 279-286.

Ozturk, E., Ocak, N., Turan, A., Erener, G., Altop, A. and Cankaya, S. (2012). Performance, carcass, gastrointestinal tract and meat quality traits, and selected blood parameters of broilers fed diets supplemented with humic substances. *Journal of the Science of Food and Agriculture*, **92** (1), 59-65.

Pandey, A., Soccol, C. R. and Laroche, C. (2008). *Current Development in Solid State Fermentation.*, Springer. Asiatech Publisher Inc. New Delhi.

Panigrahi, S. and Powell, C. J. (1991). Effects of high rates of inclusion of palm kernel meal in broiler chick diets. *Animal Feed Science and Technology*, **34** (1–2), 37-47.

Pason, P., Kosugi, A., Waeonukul, R., Tachaapaikoon, C., Ratanakhanokchai, K., Arai, T., Murata, Y., Nakajima, J. and Mori, Y. (2010). Purification and characterization of a multienzyme complex produced by *Paenibacillus curdlanolyticus* B-6. *Applied Microbiology and Biotechnology*, **85** (3), 573-580.

Pason, P., Kyu, K. L. and Ratanakhanokchai, K. (2006). *Paenibacillus curdlanolyticus* Strain B-6 xylanolytic-cellulolytic enzyme system that degrades insoluble polysaccharides. *Applied and Environmental Microbiology*, **72** (4), 2483-2490.

Patterson, J. A. and Burkholder, K. M. (2003). Application of prebiotics and probiotics in poultry production. *Poultry Science*, **82** (4), 627–631.

Perez, J., Gernat, A. and Murillo, J. (2000). Research notes: The effect of different levels of palm kernel meal in layer diets. *Poultry Science*, **79** (1), 77-79.

Petracci, M., Betti, M., Bianchi, M. and Cavani, C. (2004). Color variation and characterization of broiler breast meat during processing in Italy. *Poultry Science*, **83** (12), 2086-2092.

Piuri, Sanchez, R. and Ruzal. (1998). A novel antimicrobial activity of a *Paenibacillus polymyxa* strain isolated from regional fermented sausages. *Letters in Applied Microbiology*, **27** (1), 9-13.

Polat, U., Yesilbag, D. and Eren, M. (2011). Serum biochemical profile of broiler chickens fed diets containing Rosemary and Rosemary volatile oil. *Journal of Biology and Environmental Sciences*, **5**, 23-30.

Priabudiman, Y. and Sukaryana, Y. (2011). The influence of palm kernel cake and rice bran fermentation product mixture to the broiler carcass quality. *International Journal of Waste Resources,* **1** (2), 15-17.

Priest, F. G., Goodfellow, M., Shute, L. A. and Berkeley, R. C. W. (1987). *Bacillus amyloliquefaciens* sp. nov., nom. rev. *International Journal of Systematic Bacteriology*, **37** (1), 69-71.

Rahim, F., Sabrina, S., Rusmawati, R. and Syibli, M. (2007). Broiler small intestine villi response to feed containing palm kernel cake which fermented with Rhizopus sp. *Journal of the Indonesian Tropical Animal Agriculture*, **32** (4), 251-256.

Ramin, M., Alimon, A. R. and Ivan, M. (2010). Effects of fungal treatment on the in vitro digestion of palm kernel cake. *Livestock Research for Rural Development*, **22** (4), 82.

Rashid, S., Ibrahim, C. O. and Che Omar, I. (2012). Mannanase production by *Aspergillus niger* USM F4 via solid substrate fermentation in a shallow tray using palm kernel cake as a substrate. *Malaysian Journal of Microbiology*, **8** (4), 273-279.

Ravindran, V., Hew, L. I., Ravindran, G. and Bryden, W. L. (2005). Apparent ileal digestibility of amino acids in dietary ingredients for broiler chickens. *Animal Science*, **81** (1), 85-97.

Rivas, R., Garcia-Fraile, P., Mateos, P. F., Martinez-Molina, E. and Velazquez, E. (2006). *Paenibacillus cellulosilyticus* sp. nov., a cellulolytic and xylanolytic bacterium isolated from the bract phyllosphere of Phoenix dactylifera. *International Journal of Systematic and Evolutionary Microbiology*, **56** (12), 2777-81.

Sadhu, S. and Maiti, T. K. (2013). Cellulase production by bacteria: A review. *British Microbiology Research Journal*, **3** (3), 235-258

Saenphoom, P., Liang, J. B., Ho, Y. W., Loh, T. C. and Rosfarizan, M. (2011). Effect of enzyme treatment on chemical composition and production of reducing sugars in palm (Elaeis guineenis) kernel expeller. *African Journal of Biotechnology*, **10** (68), 15372-15377

Saenphoom, P., Liang, J. B., Ho, Y. W., Loh, T. C. and Rosfarizan, M. (2013). Effects of enzyme treated palm kernel expeller on metabolizable energy, growth performance, villus height and digesta viscosity in broiler chickens. *Asian – Australasian Journal of Animal Sciences*, **26** (4), 537-544.

SAS. (2003). Statistical analytical system. *SAS Institute Inc., Cary, NC, USA.*

Sazili, A. Q., Parr, T., Sensky, P. L., Jones, S. W., Bardsley, R. G. and Buttery, P. J. (2005). The relationship between slow and fast myosin heavy chain content, calpastatin and meat tenderness in different ovine skeletal muscles. *Meat Science*, **69** (1), 17-25.

Selle, P. H., Ravindran, V. and Partridge, G. G. (2009). Beneficial effects of xylanase and/or phytase inclusions on ileal amino acid digestibility, energy utilisation, mineral retention and growth performance in wheat-based broiler diets. *Animal Feed Science and Technology*, **153** (3–4), 303-313.

Shakila, S., Sudhakara Reddy, P., Reddy, P. V. V. S., Ramana, J. V. and Ravi, A. (2012). Effect of palm kernel meal on the performance of broilers. *Tamilnadu Journal of Veterinary and Animal Sciences,* **8** (4), 227-234.

Short, F., Gorton, P., Wiseman, J. and Boorman, K. (1996). Determination of titanium dioxide added as an inert marker in chicken digestibility studies. *Animal Feed Science and Technology*, **59** (4), 215-221.

Sindhu, I., Chhibber, S., Capalash, N. and Sharma, P. (2006). Production of cellulase-free xylanase from *Bacillus megaterium* by solid state fermentation for biobleaching of pulp. *Current Microbiology*, **53** (2), 167-72.

Soltan, M. A. (2009). Growth performance, immune response and carcass traits of broiler chicks fed on graded levels of palm kernel cake without or with enzyme supplementation. *Livestock Research for Rural Development*, **21** (3), 37.

Son, A. R., Hyun, Y., Htoo, J. K. and Kim, B. G. (2014). Amino acid digestibility in copra expellers and palm kernel expellers by growing pigs. *Animal Feed Science and Technology*, **187**, 91-97.

Sudo, M., Sakka, M., Kimura, T., Ratanakhanokchai, K. and Sakka, K. (2010). Characterization of *Paenibacillus curdlanolyticus* intracellular xylanase xyn10B encoded by the xyn10B gene. *Bioscience, Biotechnology, and Biochemistry*, **74** (11), 2358-2360.

Sukaryana, Y., Atmomarsono, U., Yunianto, V. D. and Supriyatna, E. (2010). Bioconversions of palm kernel cake and rice bran mixtures by *Trichoderma viride* toward nutritional contents. *International Journal of Science and Engineering*, **1** (2), 27 - 32.

Sulabo, R. C., Ju, W. S. and Stein, H. H. (2013). Amino acid digestibility and concentration of digestible and metabolizable energy in copra meal, palm kernel expellers, and palm kernel meal fed to growing pigs. *Journal of Animal Science*, **91** (3), 1391-1399.

Sundu, B., A. Kumar and Dingle, J. (2006). Palm kernel meal in broiler diets: its effect on chickens' performance and health. *World's Poultry Science Journal,* **62** (2), 316-325.

Sundu, B. and Dingle, J. (2002). Use of enzymes to improve the nutritional value of palm kernel meal and copra meal. In *Queensland Poultry Science Symposium* Vol. 11. Australia, pp. 1 -15.

Tachaapaikoon, C., Tanasupawat, S., Pason, P., Sornyotha, S., Waeonukul, R., Kyu, K. and Ratanakhanokchai, K. (2012). *Paenibacillus xylaniclasticus* sp. nov., a xylanolytic-cellulolytic bacterium isolated from sludge in an anaerobic digester. *The Journal of Microbiology*, **50** (3), 394-400.

Tahir, M., Saleh, F., Ohtsuka, A. and Hayashi, K. (2008). An effective combination of carbohydrases that enables reduction of dietary protein in broilers: Importance of hemicellulase. *Poultry Science*, **87** (4), 713-718.

Tanaka, H. and Phaff, H. J. (1965). Enzymatic hydrolysis of yeast cell walls I. Isolation of wall-decomposing organisms and separation and purification of lytic enzymes. *Journal of Bacteriology*, **89** (6), 1570-1580.

Tomme, P., Creagh, A. L., Kilburn, D. G. and Haynes, C. A. (1996). Interaction of polysaccharides with the N-terminal cellulose-binding domain of *Cellulomonas fimi* CenC. 1. Binding specificity and calorimetric analysis. *Biochemistry*, **35** (44), 13885-13894.

Ugwu, S. O. C., Onyimonyi, A. E. and Ozonoh, C. I. (2008). Comparative performance and haematological indices of finishing broilers fed palm kernel cake, bambara offal and rice husk as partial replacement for maize. *International Journal of Poultry Science*, **7** (3), 299-303.

van Dyk, J. S., Sakka, M., Sakka, K. and Pletschke, B. I. (2009). The cellulolytic and hemi-cellulolytic system of *Bacillus licheniformis* SVD1 and the

evidence for production of a large multi-enzyme complex. *Enzyme and Microbial Technology*, **45** (5), 372-378.

Waeonukul, R., Kyu, K. L., Sakka, K. and Ratanakhanokchai, K. (2009). Isolation and characterization of a multienzyme complex (cellulosome) of the *Paenibacillus curdlanolyticus* B-6 grown on Avicel under aerobic conditions. *Journal of Bioscience and Bioengineering*, **107** (6), 610-4.

Wenk, C. (2001). The role of dietary fibre in the digestive physiology of the pig. *Animal Feed Science and Technology*, **90** (1), 21-33.

Wing-Keong Ng and Chong, K. K. (2002). The nutritive value of palm kernel meal and the effect of enzyme supplementation in practical diets for red hybrid tilapia (*Oreochromis* sp.). *Asian Fisheries Science,* **15**, 167 - 176.

Wizna, Abbas, H., Rizal, Y., Dharma, A. and Kompiang, I. P. (2009). Improving the quality of Tapioca by-products (Onggok) as poultry feed through fermentation by *Bacillus amyloliquefaciens*. *Journal of Applied and Industrial Biotechnology in Tropical Region*, **2** (1), 1-5.

Yang, Y., Iji, P. A. and Choct, M. (2009). Dietary modulation of gut microflora in broiler chickens: a review of the role of six kinds of alternative to in-feed antibiotics. *World's Poultry Science Journal*, **65** (1), 97- 114.

Yang, Y., Iji, P. A., Kocher, A., Mikkelsen, L. L. and Choct, M. (2007). Effect of mannanoligosaccharide on growth performance, the development of gut microflora and gut function of broiler chickens raised on new litter. *Journal of Applied Poultry Research*, **16** (2), 280-288.

Zanu, H. K., Abangiba J., Arthur-Badoo W., Akparibo A. D. and R., S. (2012). Laying chickens' response to various levels of palm kernel cake in diets. *International Journal of Livestock Production*, **3** (1), 12 - 16.

Zulkifli, I., Rahayu, H. I., Alimon, A., Vidyadaran, M. and Babjee, S. (2009). Gut microflora and intestinal morphology of commercial broiler chickens and red jungle fowl fed diets containing palm kernel meal. *Archiv für Geflügelkunde*, **73** (1), 49-55.