UNIVERSITI PUTRA MALAYSIA

IMPROVING NUTRITIVE QUALITY OF PALM KERNEL CAKE FOR POULTRY FEEDING UNDER HIGH ENVIRONMENTAL TEMPERATURE

MUHAMAD HAKIM MOHD ALI HANAFIAH

IPTSM 2021 17

IMPROVING NUTRITIVE QUALITY OF PALM KERNEL CAKE FOR POULTRY FEEDING UNDER HIGH ENVIRONMENTAL TEMPERATURE

By

MUHAMAD HAKIM MOHD ALI HANAFIAH

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

March 2021

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

IMPROVING NUTRITIVE QUALITY OF PALM KERNEL CAKE FOR POULTRY FEEDING UNDER HIGH ENVIRONMENTAL TEMPERATURE

By

MUHAMAD HAKIM MOHD ALI HANAFIAH

March 2021

Chairman : Prof. Dato' Zulkifli bin Idrus, PhD
Institute : Institute of Tropical Agriculture and Food Security

There has been little information on the digestibility of amino acids (AA) of treated palm kernel cake (PKC) with many inconsistencies between existing limited studies on the apparent metabolizable energy (AME) of PKC/treated PKC for broiler chickens, especially when considering high ambient temperature into account. Besides that, previous studies on the feeding of higher PKC level in poultry diet has always been incorporated with a high level of oil to compensate for the lack of available energy due to the presence of high fiber in PKC. Hence, three experiments were carried out aimed to evaluate the effects of physical and biological treatments on the nutritive quality of PKC for broiler chickens under high environmental temperature. For the first experiment, untreated PKC (UPKC), shell-less PKC (SPKC), enzyme treated PKC (EPKC), extruded PKC (XPKC), or extruded shell-less PKC (XSPKC) were fed to broilers under two environmental temperatures (24°C or 34°C for 6 h daily) to determine AME and crude protein (CP) digestibility by using difference method. EPKC had the highest AME and CP digestibility, while high ambient temperature (34°C) lower AME and CP digestibility in all PKC. In the second trial, UPKC, EPKC, extruded PKC with lower cooking temperature (XPKC-II), and lactic acid bacteria fermented PKC (LPKC) were compared for their passage rate (ROP), AME and AA digestibility in broilers under the hot and humid environmental condition. Difference method and direct method were used to determine AME and AA digestibility, respectively. LPKC had similar AME with EPKC and XPKC-II, but demonstrated highest AA digestibility. All treatments showed no effects on ROP. The study proceeds with comparing LPKC and UPKC at different oil inclusion in broiler diets. At the finisher phase, 20% of LPKC or untreated PKC were included in broiler's diets with either 5 or 9.5% oil supplementation. LPKC and UPKC diets had no effect on broiler's growth but both diets require higher levels of dietary fat to maintain optimum growth performance. Higher level of oil supplementation in LPKC based diets reduced cecal population of *E. coli* and serum levels of TG, unlike the UPKC based diets. Feeding LPKC and UPKC diets at the finisher

phase has not affected the nutrients digestibility, but a higher level of oil supplementation does. This was seconded by changes in the digestive enzyme activity, villus height, and mRNA expression of nutrient transporters in the higher level of oil supplemented diets fed chickens. In conclusion, LAB fermentation improved the nutritive quality of PKC for heat-stress broilers, however LPKC feeding in the finisher phase had no improvement on the growth performance but reduced gut pathogenic bacteria and blood lipid concentration. Higher oil inclusion in LPKC/UPKC diet is necessary to ensure optimum growth in chicken via improved digestive function. Such formulation/strategies could be potential for utilization of agro waste-based feed in commercial poultry production under hot and humid environmental condition.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENAMBAHBAIKAN KUALITI NUTRISI ISIRUNG KELAPA SAWIT BAGI KEGUNAAN MAKANAN POLTRI DI BAWAH SUHU PERSEKITARAN YANG TINGGI

Oleh

MUHAMAD HAKIM MOHD ALI HANAFIAH

Mac 2021

Pengerusi : Prof. Dato' Zulkifli bin Idrus, PhD
Institut : Institut Pertanian Tropika dan Sekuriti Makanan

Data mengenai pencernaan asid amino (AA) dalam hampas isirung kelapa sawit (PKC) yang dirawat adalah terhad, serta wujud banyak percanggahan antara kajian yang sedia ada tentang tenaga metabolisme nyata (AME) PKC / PKC yang dirawat untuk kegunaan ayam pedaging, terutama di bawah suhu persekitaran yang tinggi. Kajian-kajian terdahulu sering meningkatkan pemberian minyak di dalam diet unggas apabila PKC diberi pada kadar yang tinggi bagi mengimbangi kekurangan tenaga yang berpunca daripada kandungan serat yang tinggi pada PKC. Oleh itu, tiga eksperimen dijalankan untuk menilai kesan rawatan fizikal dan biologi terhadap kualiti nutrien PKC untuk kegunaan ayam pedaging di bawah suhu persekitaran yang tinggi. Untuk eksperimen pertama, PKC yang tidak dirawat (UPKC), PKC kurang cangkerang (SPKC), PKC yang dirawat dengan enzim (EPKC), PKC yang diekstrusi (XPKC), atau PKC kurang cangkerang yang diekstrusi (XSPKC) diberi kepada ayam pedaging yang diternak pada suhu persekitaran yang berbeza (24°C atau 34°C selama 6 jam setiap hari) untuk menentukan nilai AME dan kadar pencernaan protein kasar (CP) dengan menggunakan kaedah perbezaan. EPKC mempunyai AME dan kadar pencernaan CP tertinggi, sementara suhu persekitaran tinggi (34°C) menjejaskan AME dan kadar pencernaan CP pada semua jenis PKC. Dalam percubaan kedua, UPKC, EPKC, PKC yang diekstrusi dengan suhu yang lebih rendah (XPKC-II), dan PKC terfermentasi bakteria asid laktik (LAB) (LPKC) diberi kepada ayam pedaging di bawah cuaca persekitaran yang panas dan lembap untuk menilai kadar laluan makanan (ROP), AME dan kadar pencernaa AA. Kaedah perbezaan digunakan untuk menentukan AME manakala kaedah langsung digunakan untuk menilai kecernaan AA. LPKC mempunyai AME yang serupa dengan EPKC dan XPKC-II, tetapi mempunyai kecernaan AA tertinggi. Semua rawatan tidak menunjukkan kesan terhadap ROP. Kajian ini diteruskan dengan membandingkan LPKC dan UPKC dengan kadar minyak yang berbeza dalam diet ayam pedaging. Pada fasa penamat, 20% LPKC atau PKC yang tidak

dirawat dimasukkan ke dalam diet ayam pedaging dengan tambahan 5 atau 9.5% minyak. Diet LPKC dan UPKC yang tidak dirawat tidak mempengaruhi pertumbuhan ayam pedaging tetapi kedua-dua diet memerlukan kandungan minyak yang lebih tinggi untuk mengekalkan prestasi pertumbuhan yang optimum. Kadar minyak yang lebih tinggi dalam diet LPKC mengurangkan populasi *E. coli* di dalam usus dan kadar trigliserida dalam darah, berbanding diet PKC. Kadar pemberian minyak yang lebih tinggi meningkatkan pencernaan nutrient di dalam diet LPKC dan UPKC. Ini dibuktikan oleh perubahan dalam aktiviti enzim pencernaan, ketinggian villus, dan ekspresi mRNA pengangkut nutrien pada kadar pemberian minyak yang lebih tinggi di dalam diet ayam pedaging. Kesimpulannya, fermentasi LAB meningkatkan kualiti nutrien PKC untuk kegunaan ayam dibawah tekanan haba, namun pemberian makanan LPKC pada fasa penamat tidak menunjukkan peningkatan pada prestasi pertumbuhan tetapi mengurangkan bakteria patogen di dalam usus dan kandungan lemak di dalam darah. Pemberian kadar minyak yang lebih tinggi dalam diet LPKC / UPKC diperlukan untuk memastikan pertumbuhan ayam yang optimum melalui pembaikan fungsi pencernaan. Formulasi diet atau strategi ini berpotensi untuk memanfaatkan penggunaan makanan ternakan yang berasaskan sisa agro-industri dalam produksi unggas komersial di bawah cuaca persekitaran yang panas dan lembap.

ACKNOWLEDGEMENTS

First and foremost, I am very grateful to Allah SWT for all His blessings and mercy, which only by His willing I am able to complete my PhD journey.

I would like to express my sincerest thanks to my respected main supervisor, Professor Dato' Dr. Zulkifli Idrus, for allowing me to be part of his research team, and all of support and guidance, technically and morally throughout my study period. I am also very thankful to both co-supervisor Professor Dr. Rosfarizan Mohamed and Dr. Liang Juan Boo for all the help and guidance. Special thanks should be given to my former supervisor Dr. Abdoreza Soleimani Farjam, and former post-doctoral researcher Dr. Elmutaz Atta Awad, for all their help, support, guidance, and friendship.

Special thanks to all ITAFoS staffs, Dr. Suriyah, Dr. Huzairi, Mr. Eddy, Ms. Ummi, Mr. Fazmen, Mr. Farhan, Mr. Zaidi, Mr. Faizol, Ms. Haireen, Ms. Hashimah, and Ms. Nurhafizah, who have been offering assistance and guidance for all the process involved with my project, either in the farm, laboratory, or office.

Most importantly, I would like to express my highest gratitude to my family, especially to my mother and father, Hajah Maznah and Haji Ali Hanafiah whom their blessings and prayers makes this journey and its destinations achievable, and to my beloved wife, Afifah and our cheerful sons, Umar and Uthman, which have been my source of motivation to steadfast in this PhD journey.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

The members of the Supervisory Committee were as follows:

Zulkifli bin Idrus, PhD
Professor Dato'
Institute of Tropical Agriculture and Food Security
Universiti Putra Malaysia
(Chairman)

Rosfarizan binti Mohamad, PhD
Professor
Faculty of Biotechnology and Biomolecular Science
Universiti Putra Malaysia
(Member)

Liang Juan Boo, PhD
Principal Research Fellow
Institute of Tropical Agriculture and Food Security
Universiti Putra Malaysia
(Member)

_____

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 August 2021

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.: Muhamad Hakim Mohd Ali Hanafiah GS43981

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

AA	Amino acids
AABA	L-α-Amino-n-Butyric Acid
ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
AIAAD	Apparent Ileal Amino Acids Digestibility
AID	Apparent Ileal Digestibility
AIDCP	Apparent Ileal Digestibility of Crude Protein
AME	Apparent Metabolisable Energy
AME_n	Nitrogen-corrected Apparent Metabolisable Energy
ANOVA	Analysis of Variance
AOAC	Association Official Agricultural Chemists
ATCC	American Type Culture Collection
BWG	Body Weight Gain
cm	Centimetre
CF	Crude Fiber
CP	Crude Protein
DCP	Dicalcium phosphate
DDGS	Dried Distillers Grain with Solubles
DM	Dry Matter
DNA	Deoxyribonucleic Acid
DOSM	Department of Statistics Malaysia
DVS	Department of Veterinary Service
EE	Ether Extract
EFB	Empty Fruit Bunch
EU	European Union
FAMA	Federal Agricultural Marketing Authority
FCR	Feed Conversion Ratio
FI	Feed Intake
g	Gram
GE	Gross Energy
GIT	Gastrointestinal Tract
GLM	General Linear Models
h	Hour
HCL	Hydrochloric Acids
HDL-C	High Density Lipoprotein Cholesterol
HPLC	High Performance Liquid Chromatography
Hz	Hertz

IACUC	Institutional Animal Care and Use Committee
IB	Infectious Bronchitis
kcal	Kilocalorie
kg	Kilogram
L	Liter
LAB	Lactic Acid Bacteria
LDL-C	Low Density Lipoprotein Cholesterol
M	Molar
MCP	Monocalcium phosphate
ME	Metabolisable Energy
mg	Milligram
mm	Millimetre
MPOB	Malaysian Palm Oil Board
MRS	De Man, Rogosa, Sharpe
MRT	Mean Retention Time
MSM	Minimal Salt Media
ND	Newcastle Disease
NDF	Neutral Detergent Fiber
NRC	National Research Council
NSP	Non-Starch Polysaccharide
OM	Organic Matter
OPF	Oil Palm Frond
PCR	Polymerase Chain Reaction
pH	Hydrogen Ion Concentration
PKC	Palm Kernel Cake
PKE	Palm Kernel Expeller
PKM	Palm Kernel Meal
POME	Palm Oil Mill Effluent
POS	Palm Oil Sludge
PPF	Palm Pressed Fiber
RM	Ringgit Malaysia
RNA	Ribonucleic Acids
ROP	Rate of Passage
rpm	Revolution per minute
SAS	Statistical Analysis System
SEM	Standard Error of Means
SR	Sulfonamide-Resistant
SSF	Solid State Fermentation
TC	Total Cholesterol
TG	Triglycerides

TiO_2	Titanium Dioxide
TME	True Metabolisable Energy
TME_n	Nitrogen-corrected True Metabolisable Energy
IU	International Unit
u/d	Undetected
UPM	Universiti Putra Malaysia
VFA	Volatile Fatty Acids
°C	Degree Celsius
× g	Gravitational Force
µg	Microgram
µL	Microliter
µm	Micrometre
µmole	Micromole

CHAPTER 1

INTRODUCTION

According to the Fourth Malaysian Agriculture Policy (2011-2020) , efforts will be taken to encourage the local animal feed production, particularly in escalating the research and development of locally produced feed ingredient in non-ruminant feed (includes poultry). The current self-sufficiency of poultry meat and eggs are 98.2% and 113.6%, respectively and it contributes to 73% of the RM22 billion livestock industry in the country which the ex-farm value of poultry meat and eggs were RM 11.6 billion and RM 4.6 billion, respectively (Department of Statistics Malaysia, 2020; Department of Veterinary Service, 2020). However, the industry is not sustainable in the long term due to heavy dependence on imported feed and increasing the cost of inputs. Malaysia is importing feedstuffs to the value of above RM2 billion annually (Federal Agricultural Marketing Authority, 2014).

Data from Malaysian Palm Oil Board (2020) showed that Malaysia palm oil industry produces over 2 million tonnes of palm kernel cake (PKC), a waste from palm oil extraction process, annually. The local poultry industry and scientists have shown interest in PKC to be an alternative feed to the corn-soy based feeds that have been used widely, due to its abundancy and low pricing. As per comparison, the current price of PKC (RM499/tonne) is lower by 42% than corn grain (RM860/tonne) (Ministry of Plantation Industry and Commodities, 2020; National Agricultural Statistics Service, 2021). In Malaysia, PKC has been successfully used as a ruminant feed rather than as a feed for monogastric animals (Zulkifli et al., 2003). Since PKC is a by-product of the palm oil extraction, it holds up an average amount of carbohydrate and protein, with lacks several essential amino acids. However, the use of PKC in poultry feeding is limited due to its high fiber content (17%), high insoluble non-starch polysaccharides (NSP) such as mannan (78%), which reduce the digestibility of nutrient and subsequently lower the metabolizable energy (ME) (1300 kcal kg^{-1}) (Sharmila et al., 2014). Such limitation led to low yet inconsistent recommended inclusion level for poultry feeding, ranges from 10-20% (Alimon, 2004).

Several treatments on PKC have recently been tested to reduce and/or eliminate the constraints of using PKC in poultry diets (Sharmila et al., 2014). The methods used to achieve this goal are either physically, chemically, biologically or by combining those treatments. However, there is limited data available on the ME, CP, and AA digestibility of treated PKC, which essential for the modern practice of diets formulation with specific nutrient requirements. Besides that, few treatments were unable to improve the feed efficiency in chicken (Chen et al., 2018; Saenphoom et al., 2013), despite the improvement noticed on PKC nutritive quality which may suggest low nutrient utilization, even in treated PKC diets. Such discrepancies may untangle with an in-depth investigation on broiler's digestive functions upon feeding of treated PKC/untreated PKC.

Limiting the use of fibrous ingredients in poultry diets under heat stress conditions was recommended (Chong, 1999; Leeson & Summers, 1997). High fiber diets showed lower availability of essential amino acids in heat-stressed chickens, which later compromised their growth performance (Koelkebeck et al., 1998). As Malaysia is experiencing hot and humid climate throughout the year, the feeding of PKC to broiler chickens under high ambient temperatures is of concern. Plus, there is no information on the suitability of treated PKC for heat-stressed broilers, thus it is essential to determine the nutrient availability of treated PKC under high ambient temperature.

Previous studies on PKC in poultry involved the inclusion of high levels of oil to replace the metabolizable energy of the diet (Alshelmani et al., 2016a; Saenphoom et al., 2013) which initially contributed by corn. Although high dietary fat in the diet may be associated with higher fat deposition in chickens, it also may improve fiber tolerance in heat stressed chickens (Zulkifli et al., 2003). Higher dietary fat supplementation has shown to improve nutrient utilization by increase feed passage time (Mateos et al., 1982). Thus, the important role of dietary fat in PKC fed broilers under the high environmental temperature need to be explored.

1.1 Hypothesis

Overall, it is expected that the treatments on PKC will improve its nutritive quality for heat-stressed broiler, and its combination with higher oil level supplementation will ensure optimum growth by improving the digestive system in broiler chicken under high environmental temperature.

1.2 Objective of the study

The purpose of this experiment was to evaluate the effects of physical and biological treatments on the nutritive quality of PKC for broiler chickens under high environmental temperature.

1.2.1 Specific objectives

1.2.1.1 To determine the AME and AID of CP of shell-less, enzyme treated, extruded, and extruded shell-less PKC in broilers under unheated and heated conditions.

1.2.1.2 To compare the rate of passage (ROP), AME, and AIAAD of the enzyme-fermented PKC, extruded PKC, and lactic acid bacteria-fermented PKC in broilers under hot tropical climate.

1.2.1.3 To study the effects of high dietary oil inclusion in untreated PKC or treated PKC containing finisher diets on broiler's growth performance, cecal microbial population, and blood lipid profile concentration under hot tropical climate.

1.2.1.4 To determine the ileal nutrient digestibility, digestive enzyme activity, intestinal morphology, and nutrient transporters mRNA expressions in broiler chickens fed with PKC based diets at different levels of oil supplementation.

REFERENCES

Abdollahi, M. R., Hosking, B., & Ravindran, V. (2015). Nutrient analysis, metabolisable energy and ileal amino acid digestibility of palm kernel meal for broilers. *Animal Feed Science and Technology, 206*, 119-125. doi:10.1016/j.anifeedsci.2015.05.019

Abdollahi, M. R., Ravindran, V., & Amerah, A. M. (2016). Influence of palm kernel meal inclusion and exogenous enzyme supplementation on growth performance, energy utilization and nutrient digestibility in young broilers. *Asian-Australasian Journal of Animal Sciences, 29*(4), 539-548. doi:10.1111/jpn.12472

Abidin, Z. & Khatoon, A. (2013). Heat stress in poultry and the beneficial effects of ascorbic acid (vitamin C) supplementation during periods of heat stress. *World's Poultry Science Journal, 69*(1), 135-152. doi:10.1017/s0043933913000123

Ahmed, A., Zulkifli, I., Farjam, A. S., Abdullah, N., & Liang, J. B. (2014a). Extrusion enhances metabolizable energy and ileal amino acids digestibility of canola meal for broiler chickens. *Italian Journal of Animal Science, 13*(1), 3032-3032. doi:10.4081/ijas.2014.3032

Ahmed, A., Zulkifli, I., Farjam, A. S., Abdullah, N., Liang, J. B., & Awad, E. A. (2014b). 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), 3293-3293. doi:10.4081/ijas.2014.3293

Ajila, C. M., Brar, S. K., Verma, M., Tyagi, R. D., Godbout, S., & Valero, J. R. (2012). Bio-processing of agro-byproducts to animal feed. *Crit Rev Biotechnol, 32*(4), 382-400. doi:10.3109/07388551.2012.659172

Al-Khalaifah, H. S., Shahin, S. E., Omar, A. E., Mohammed, H. A., Mahmoud, H. I., & Ibrahim, D. (2020). Effects of graded levels of microbial fermented or enzymatically treated dried brewer's grains on growth, digestive and nutrient transporter genes expression and cost effectiveness in broiler chickens. *BMC Vet Res, 16*(1), 424. doi:10.1186/s12917-020-02603-0

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

Almeida, F. N., Htoo, J. K., Thomson, J., & Stein, H. H. (2014). Effects of heat treatment on the apparent and standardized ileal digestibility of amino acids in canola meal fed to growing pigs. *Animal Feed Science and Technology, 187*, 44-52. doi:10.1016/j.anifeedsci.2013.09.009

Almirall, M. & Esteve-Garcia, E. (1994). Rate of passage of barley diets with chromium oxide: Influence of age and poultry strain and effect of β-glucanase supplementation. *Poultry Science, 73*(9), 1433-1440.

Almirall, M., Francesch, M., Perez-vendrell, A. M., & Esteve-garcia, J. B. E. (1995). The differences in intestinal viscosity produced by barley and β-glucanase alter digesta enzyme activities and ileal nutrient digestibilities more in broiler chicks than in cocks. *American Institute of Nutrition, 125*(4), 947-955.

Alshelmani, M. I. (2015). *Effect of feeding palm kernel cake fermented by fiber degrading bacteria on performance of broiler chicken.* (Doctoral dissertation). Universiti Putra Malaysia, Serdang, Malaysia,

Alshelmani, M. I., Loh, T. C., Foo, H. L., Lau, W. H., & Sazili, A. Q. (2013). Characterization of cellulolytic bacterial cultures grown in different substrates. *The Scientific World Journal, 2013*.

Alshelmani, M. I., Loh, T. C., Foo, H. L., Lau, W. H., & Sazili, A. Q. (2014). Biodegradation of palm kernel cake by cellulolytic and hemicellulolytic bacterial cultures through solid state fermentation. *The Scientific World Journal, 2014*. doi:10.1155/2014/729852

Alshelmani, M. I., Loh, T. C., Foo, H. L., Sazili, A. Q., & Lau, W. H. (2016a). Effect of feeding different levels of palm kernel cake fermented by Paenibacillus polymyxa ATCC 842 on broiler growth performance, blood biochemistry, carcass characteristics, and meat quality. *Animal Production Science, 57*, 839-848. doi:10.1071/AN15359

Alshelmani, M. I., Loh, T. C., Foo, H. L., Sazili, A. Q., & Lau, W. H. (2016b). Effect of feeding different levels of palm kernel cake fermented by Paenibacillus polymyxa ATCC 842 on nutrient digestibility, intestinal morphology, and gut microflora in broiler chickens. *Animal Feed Science and Technology, 216*, 216-224. doi:10.1016/j.anifeedsci.2016.03.019

Alshelmani, M. I., Loh, T. C., Foo, H. L., Sazili, A. Q., & Lau, W. H. (2017). Effect of solid state fermentation on nutrient content and ileal amino acids digestibility of palm kernel cake in broiler chickens. *Indian Journal of Animal Sciences, 87*(9), 1135-1140.

Álvarez-Cervantes, J., Hernández-Domínguez, E. M., Arana-Cuenca, A., Díaz-Godínez, G., & Mercado-Flores, Y. (2013). Purification and characterization of xylanase SRXL1 from Sporisorium reilianum grown in submerged and solid-state fermentation. *BioResources, 8*(4), 5309-5318.

Annison, G. & 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*(November), 232-242. doi:10.1079/WPS19910019

AOAC. (1990). *Official methods of analysis of the Association of Official Analytical Chemists* (15th ed.): Arlington, VA: AOAC Inc.

Arija, I., Centeno, C., Viveros, A., Brenes, A., Marzo, F., Illera, J. C., & Silvan, G. (2006). Nutritional evaluation of raw and extruded kidney bean (Phaseolus vulgaris L. var. Pinto) in chicken diets. *Poultry Science, 85*(4), 635-644. doi:10.1093/ps/85.4.635

Ashayerizadeh, A., Dastar, B., Shargh, M. S., Mahoonak, A. R. S., & Zerehdaran, S. (2018). Effects of feeding fermented rapeseed meal on growth performance, gastrointestinal microflora population, blood metabolites, meat quality, and lipid metabolism in broiler chickens. *Livestock Science, 216*, 183-190. doi:10.1016/j.livsci.2018.08.012

Awad, E. A. (2016). *Effects of feeding low-protein diets fortified with amino acids on broiler chickens under high environmental temperatures.* (Doctoral dissertation). Universiti Putra Malaysia, Serdang, Malaysia,

Awad, E. A., Idrus, Z., Soleimani Farjam, A., Bello, A. U., & Jahromi, M. F. (2018). Growth performance, duodenal morphology and the caecal microbial population in female broiler chickens fed glycine-fortified low protein diets under heat stress conditions. *Br Poult Sci, 59*(3), 340-348. doi:10.1080/00071668.2018.1440377

Awad, E. A., Zulkifli, I., Farjam, A. S., & Chwen, L. T. (2014). Amino acids fortification of low-protein diet for broilers under tropical climate. 2. Nonessential amino acids and increasing essential amino acids. *Italian Journal of Animal Science, 13*(3), 3297-3297. doi:10.4081/ijas.2014.3297

Awad, E. A., Zulkifli, I., Farjam, A. S., Loh, T. C., Hossain, M. A., & Ahmed, A. (2016). Effect of low-protein diet , gender and age on the apparent ileal amino acid digestibility in broiler chickens raised under hot-humid tropical condition. *Indian Journal of Animal Sciences, 86*(6), 696-701.

Azizi, M. N., Loh, T. C., Foo, H. L., & Chung, E. L. T. (2021). Is palm kernel cake a suitable alternative feed ingredient for poultry? *Animals, 11*(2), 338. doi:10.3390/ani11020338

Babatunde, G. M., Fetuga, B. L., Odumosu, O., & Oyenuga, V. A. (1975). Palm kernel meal as the major protein concentrate in the diets of pigs in the tropics. *Journal of the Science of Food and Agriculture, 26*(9), 1279-1291. doi:10.1002/jsfa.2740260906

Bailey, M. J., Biely, P., & Poutanen, K. (1992). Interlaboratory testing of methods for assay of xylanase activity. *Journal of Biotechnology, 23*(3), 257-270. doi:10.1016/0168-1656(92)90074-J

Beloshapka, A., Buff, P., Fahey, G., & Swanson, K. (2016). Compositional analysis of whole grains, processed grains, grain co-products, and other

carbohydrate sources with applicability to pet animal nutrition. *Foods, 5*(4), 23-23. doi:10.3390/foods5020023

Bonnet, S., Geraert, P. A., Lessire, M., Carre, B., & Guillaumin, S. (1997). Effect of high ambient temperature on feed digestibility in broilers. *Poultry Science, 76*(6), 857-863. doi:10.1093/ps/76.6.857

Brenes, A., Viveros, A., Centeno, C., Arija, I., & Marzo, F. (2008). Nutritional value of raw and extruded chickpeas (Cicer arietinum L.) for growing chickens. *Spanish Journal of Agricultural Research, 6*(4), 537-545. doi:10261/125136

Brue, R. N. & Latshaw, J. D. (1985). Energy utilization by the broiler chicken as affected by various fats and fat levels. *Poultry Science, 64*(11), 2119-2130. doi:10.3382/ps.0642119

Bryden, W. L., Li, X., Ravindran, G., Hew, L. I., & Ravindran, V. (2009). *Ileal digestible amino acid values in feedstuffs for poultry*. Canberra: Rural Industries Research and Development Corporation.

Cahaner, A., Pinchasov, Y., Nir, I., & NITSAN, Z. (1995). Effects of dietary protein under high ambient temperature on body weight, breast meat yield, and abdominal fat deposition of broiler stocks differing in growth rate and fatness. *Poultry Science, 74*(6), 968-975.

Cao, B. H., Zhang, X. P., Guo, Y. M., Karasawa, Y., & Kumao, T. (2003). Effects of dietary cellulose levels on growth, nitrogen utilization, retention time of diets in digestive tract and caecal microflora of chickens. *Asian-Australasian Journal of Animal Sciences, 16*(6), 863-866. doi:10.5713/ajas.2003.863

Caspary, W. F. (1992). Physiology and pathophysiology of intestinal absorption. *American Journal of Clinical Nutrition, 55*, 299S-308S. doi:10.2169/naika.100.139

Charles, D. (2002). Responses to the thermal environment. *Poultry Environment Problem, A guide to solution. Nottingham University Press, Nottingham, United Kingdom*, 1-16.

Chen, H., Mao, X., Yin, J., Yu, B., He, J., Che, L., . . . Chen, D. (2015a). Comparison of jejunal digestive enzyme activities, expression of nutrient transporter genes, and apparent fecal digestibility in weaned piglets fed diets with varied sources of fiber. *Journal of Animal and Feed Sciences, 24*(1), 41-47. doi:10.22358/jafs/65651/2015

Chen, W. L., Jahromi, M. F., Candyrine, S. C. L., Liang, J. B., Abdullah, N., & Idrus, Z. (2018). Enzymatic hydrolysis drastically reduces fibre content of palm-kernel expeller, but without enhancing performance in broiler chickens. *Animal Production Science, 59*, 2131-2137.

Chen, W. L., Liang, J. B., Jahromi, M. F., Abdullah, N., Ho, Y. W., & Tufarelli, V. (2015b). Enzyme treatment enhances release of prebiotic oligosaccharides from palm kernel expeller. *BioResources, 10*(1), 196-209. doi:10.15376/biores.10.1.196-209

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

Chen, X., Murdoch, R., Zhang, Q., Shafer, D. J., & Applegate, T. J. (2016). Effects of dietary protein concentration on performance and nutrient digestibility in Pekin ducks during aflatoxicosis. *Poultry Science, 95*(4), 834-841. doi:10.3382/ps/pev378

Chin, F. Y. (2002). Utilization of palm kernel cake (PKC) as feed in Malaysia. *Asian Livestock Magazine,* 19-23.

Chin, F. Y. (2008). *Palm kernel cake (PKC) as a supplement for fattening and dairy cattle in Malaysia*. Paper presented at the 7th Meeting of the Regional Working Group on Grazing and Feed Resources. Forage Development in Southeast Asia; Strategies and Impact.

Choct, M. (1997). Feed non-starch polysaccharides: Chemical structures and nutritional significance. *Feed Milling International, 191*(June), 13-26.

Choct, M. & Annison, G. (1992). Anti-nutritive effect of wheat pentosans in broiler chickens: roles of viscosity and gut microflora. *British Poultry Science, 33*(4), 821-834. doi:10.1080/00071669208417524

Choct, M., Hughes, R. J., & Bedford, M. R. (1999). Effects of a xylanase on individual bird variation, starch digestion throughout the intestine, and ileal and caecal volatile fatty acid production in chickens fed wheat. *Br Poult Sci, 40*(3), 419-422. doi:10.1080/00071669987548

Choct, M., Hughes, R. J., Wang, J., Bedford, M. R., Morgan, A. J., & Annison, G. (1996). Increased small intestinal fermentation is partly responsible for the anti-nutritive activity of non-starch polysaccharides in chickens. *Br Poult Sci, 37*(3), 609-621. doi:10.1080/00071669608417891

Choe, D. W., Loh, T. C., Foo, H. L., Hair-Bejo, M., & 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. doi:10.1080/00071668.2012.659653

Chong, C. H. (1999). *Improving utilization of poultry feedstuffs with supplemental amino acids and enzymes.* (Doctoral dissertation). The University of Manitoba, Winnipeg, Canada,

Christopherson, R. & Young, B. (1986). Effects of cold environments on domestic animals. *NATO advanced science institutes series: Series A: Life sciences (USA)*.

Coombe, J. B. & Kay, R. N. B. (1965). Passage of digesta through the intestines of the sheep: Retention times in the small and large intestines. *British Journal of Nutrition, 19*, 325-338. doi:10.1079/BJN19650031

Cowieson, A. J., Toghyani, M., Kheravii, S. K., Wu, S. B., Romero, L. F., & Choct, M. (2019). A mono-component microbial protease improves performance, net energy, and digestibility of amino acids and starch, and upregulates jejunal expression of genes responsible for peptide transport in broilers fed corn/wheat-based diets supplemented with xylanase and phytase. *Poult Sci, 98*(3), 1321-1332. doi:10.3382/ps/pey456

Daghir, N. (2009). Nutritional strategies to reduce heat stress in broilers and broiler breeders. *Lohmann information, 44*(1), 6-15. Retrieved from http://d-nb.info/994000170/34

Dale, N. M. & Fuller, H. L. (1980). Effect of diet composition on feed intake and growth of chicks under heat stress. II. Constant vs. cycling temperatures. *Poult Sci, 59*, 1439-1441.

Daskiran, M., Teeter, R., Fodge, D., & Hsiao, H. (2004). An evaluation of endo-β-D-mannanase (Hemicell) effects on broiler performance and energy use in diets varying in β-mannan content. *Poultry Science, 83*(4), 662-668.

de Vries, S., Pustjens, A. M., Schols, H. A., Hendriks, W. H., & Gerrits, W. J. J. (2012). Improving digestive utilization of fiber-rich feedstuffs in pigs and poultry by processing and enzyme technologies: A review. *Animal Feed Science and Technology, 178*(3-4), 123-138. doi:10.1016/j.anifeedsci.2012.10.004

Dégen, L., Halas, V., & 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. doi:10.1080/09064700701372038

Demain, A. L. (1999). Pharmaceutically active secondary metabolites of microorganisms. *Applied Microbiology and Biotechnology, 52*(4), 455-463.

Department of Statistics Malaysia. (2020). Press release - Supply and utilization accounts selected agricultural commodities, Malaysia 2015-2019. Retrieved from https://www.dosm.gov.my/v1/index.php?r=column/pdfPrev&id=OTM1TDMzS1IvYm5mU1JiU1Fwekt3UT09

Department of Veterinary Service. (2020). *Livestock Statistics 2019-2020*. Retrieved from http://www.dvs.gov.my/index.php/pages/view/3338

Dharmaraj, S. (2010). Marine Streptomyces as a novel source of bioactive substances. *World Journal of Microbiology and Biotechnology, 26*(12), 2123-2139.

Donkoh, A. (1989). Ambient temperature: A factor affecting performance and physiological response of broiler chickens. *International Journal of Biometeorology, 33*(4), 259-265. doi:10.1007/BF01051087

Dowling, R. H. & Booth, C. C. (1967). Structural and functional changes following small intestinal resection in the rats. *Clinical Science, 32*, 139-149.

Düsterhöft, E. M., Voragen, A. G. J., & Engels, F. M. (1991). Non-starch polysaccharides from sunflower (Helianthus annuus) meal and palm kernel (Elaeis guineenis) meal - preparation of cell wall material and extraction of polysaccharide fractions. *Journal of the Science of Food and Agriculture, 55*(3), 411-422. doi:10.1002/jsfa.2740550309

Ebrahimi, R., Jahromi, M. F., Liang, J. B., Farjam, A. S., Shokryazdan, P., & Idrus, Z. (2015). Effect of dietary lead on intestinal nutrient transporters mRNA expression in broiler chickens. *BioMed Research International, 2015*. doi:10.1155/2015/149745

Emmerson, D. A. (1997). Commercial approaches to genetic selection for growth and feed conversion in domestic poultry. *Poultry Science, 76*(8), 1121-1125. doi:10.1093/ps/76.8.1121

Ezieshi, E. V. & 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.

Faridah, H. S., Goh, Y. M., Noordin, M. M., & Liang, J. B. (2020). Extrusion enhances apparent metabolizable energy, ileal protein and amino acid digestibility of palm kernel cake in broilers. *Asian-Australas J Anim Sci, 33*(12), 1965-1974. doi:10.5713/ajas.19.0964

Farouk, M. M., Al-Mazeedi, H. M., Sabow, A. B., Bekhit, A. E. D., Adeyemi, K. D., Sazili, A. Q., & Ghani, A. (2014). Halal and kosher slaughter methods and meat quality: A review. *Meat Science, 98*(3), 505-519. doi:10.1016/j.meatsci.2014.05.021

Farrell, D. & Swain, S. (1977). Effects of temperature treatments on the energy and nitrogen metabolism of fed chickens. *British Poultry Science, 18*(6), 735-748.

Federal Agricultural Marketing Authority. (2014). *FAMA Marketing Statistics 2014*. Ministry of Agriculture and Agro-based Industry, Federal Agricultural Marketing Authority.

Feng, J., Liu, X., Xu, Z. R., Wang, Y. Z., & Liu, J. X. (2007). Effects of fermented soybean meal on digestive enzyme activities and intestinal morphology in broilers. *Poult Sci, 86*(6), 1149-1154. doi:10.1093/ps/86.6.1149

Foo, H. L., Loh, T. C., Lim, Y. S., Shukriyah, M. H., Kufli, C. N., & 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. doi:10.3923/pjn.2003.228.233

Foreign Agricultural Service. (2020). *Palm oil explorer 2020*. U.S. Department of Agriculture, Foreign Agricultural Service. Retrieved from https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=4243000&sel_year=2020&rankby=Production

Fuller, H. L. & Rendon, M. (1979). Energetic efficiency of corn oil and poultry fat at different levels in broiler diets. *Poultry Science, 58*(5), 1234-1238. doi:10.3382/ps.0581234

Gilbert, E. R., Li, H., Emmerson, D. A., Webb, K. E., & Wong, E. A. (2007). Developmental regulation of nutrient transporter and enzyme mRNA abundance in the small intestine of broilers. *Poultry Science, 86*(8), 1739-1753. doi:10.1093/ps/86.8.1739

Goering, H. K. & Van Soest, P. J. (1970). Forage fiber analyses (apparatus, reagents, prcedures, and some applications). In: U.S. Agricultural Research Service.

González-Alvarado, J. M., Jiménez-Moreno, E., González-Sánchez, D., Lázaro, R., & Mateos, G. G. (2010). Effect of inclusion of oat hulls and sugar beet pulp in the diet on productive performance and digestive traits of broilers from 1 to 42 days of age. *Animal Feed Science and Technology, 162*(1-2), 37-46. doi:10.1016/j.anifeedsci.2010.08.010

Gonzalez-Esquerra, R. & Leeson, S. (2005). Effects of acute versus chronic heat stress on broiler response to dietary protein. *Poult Sci, 84*, 1562-1569.

Grajek, W. (1987). Comparative studies on the production of cellulases by thermophilic fungi in submerged and solid-state fermentation. *Applied Microbiology and Biotechnology, 26*(2), 126-129. doi:10.1007/BF00253895

Gunawardana, P., Roland, D. A., & Bryant, M. M. (2009). Effect of dietary energy, protein, and a versatile enzyme on hen performance, egg solids, egg composition, and egg quality of Hy-Line W-36 hens during second cycle, phase two. *Journal of Applied Poultry Research, 18*(1), 43-53. doi:10.3382/japr.2008-00047

Guo, S., Liu, D., Zhao, X., Li, C., & Guo, Y. (2014). Xylanase supplementation of a wheat-based diet improved nutrient digestion and mRNA expression

of intestinal nutrient transporters in broiler chickens infected with Clostridium perfringens. *Poultry Science, 93*, 94-103. doi:10.3382/ps.2013-03188

Gutierrez, O., Zhang, C., Caldwell, D., Carey, J., Cartwright, A., & Bailey, C. (2008). Guar meal diets as an alternative approach to inducing molt and improving Salmonella Enteritidis resistance in late-phase laying hens. *Poultry Science, 87*(3), 536-540.

Habashy, W. S., Milfort, M. C., Adomako, K., Attia, Y. A., Rekaya, R., & Aggrey, S. E. (2017). Effect of heat stress on amino acid digestibility and transporters in meat-type chickens Gene Expression of Amino Acid. *Poultry Science*(March), 1-8. doi:10.3382/ps/pex027

Hai, L., Rong, D., & Zhang, Z. Y. (2000). The effect of thermal environment on the digestion of broilers. *Journal of Animal Physiology and Animal Nutrition, 83*(2), 57-64.

Heres, L., Engel, B., van Knapen, F., de Jong, M. C., Wagenaar, J. A., & Urlings, H. A. (2003). Fermented liquid feed reduces susceptibility of broilers for Salmonella enteritidis. *Poult Sci, 82*(4), 603-611. doi:10.1093/ps/82.4.603

Hetland, H. & Svihus, B. (2001). Effect of oat hulls on performance, gut capacity and feed passage time in broiler chickens. *British Poultry Science, 42*(3), 354-361. doi:10.1080/00071660120055331

Homayouni, A., Payahoo, L., & Azizi, A. (2012). Effects of probiotics on lipid profile: A review. *American Journal of Food Technology, 7*(5), 251-265.

Honda, K., Kamisoyama, H., Isshiki, Y., & Hasegawa, S. (2009). Effects of dietary fat levels on nutrient digestibility at different sites of chicken intestines. *The Journal of Poultry Science, 46*, 291-295.

Honda, K., Kamisoyama, H., Isshiki, Y., & Hasegawa, S. (2010). Effects of different dietary fat levels on amino acid digestibility at different sites of chicken intestines. *The Journal of Poultry Science, 47*, 227-235.

Hu, Y., Smith, D. E., Ma, K., Jappar, D., Thomas, W., & Hillgren, K. M. (2008). Targeted disruption of peptide transporter pept1 gene in mice significantly reduces dipeptide absorption in intestine. *Molecular Pharmaceutics, 5*(6), 1122-1130. doi:10.1021/mp8001655

Hulan, H. W. & Bird, F. H. (1972). Effect of fat level in isonitrogenous diets on the composition of avian pancreatic juice. *The Journal of Nutrition, 102*, 459-468.

Hutagalung, R. I. (1980). *Availability of feedstuffs for farm animals.* Paper presented at the Proceedings Abstract. First Asia-Australian Animal Science Congress, Abstract (No. 4).

Ibrahim, D., Moustafa, A., Shahin, S. E., Sherief, W., Abdallah, K., Farag, M. F. M., . . . Ibrahim, S. M. (2021). Impact of Fermented or Enzymatically Fermented Dried Olive Pomace on Growth, Expression of Digestive Enzyme and Glucose Transporter Genes, Oxidative Stability of Frozen Meat, and Economic Efficiency of Broiler Chickens. *Front Vet Sci, 8*, 644325. doi:10.3389/fvets.2021.644325

Iji, P. A., Saki, A. A., & Tivey, D. R. (2001). Intestinal structure and function of broiler chickens on diets supplemented with a mannan oligosaccharide. *Journal of the Science of Food and Agriculture, 81*, 1186-1192. doi:10.3390/ijms9112205

Incharoen, T., Yamauchi, K.-e., Erikawa, T., & Gotoh, H. (2016). Histology of intestinal villi and epithelial cells in chickens fed low-crude protein or low-crude fat diets. *Italian Journal of Animal Science, 9*(4). doi:10.4081/ijas.2010.e82

Iyayi, E. A. & 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. doi:10.3923/ijps.2005.76.80

Izuddin, W. I., Loh, T. C., Foo, H. L., Samsudin, A. A., & Humam, A. M. (2019). Postbiotic L. plantarum RG14 improves ruminal epithelium growth, immune status and upregulates the intestinal barrier function in post-weaning lambs. *Sci Rep, 9*(1), 9938. doi:10.1038/s41598-019-46076-0

Jaafar, M. D. & Jarvis, M. C. (1992). Mannan of oil palm kernel. *Phytochemistry, 31*(2), 463-464. doi:10.1016/0031-9422(92)90017-K

Jackson, M., Fodge, D., & Hsiao, H. (1999). Effects of beta-mannanase in corn-soybean meal diets on laying hen performance. *Poultry Science, 78*(12), 1737-1741.

Jahari, M. A., Roslan, M. A. H., Mustafa, S., Abdullah, N., & Idrus, Z. (2020). Enhancing broilers performance fed palm kernel expeller (PKE) feeds fortified with supplements. *Journal of Biochemistry, Microbiology, and Biotechnology, 8*(2), 33-39.

Jahromi, M. F., Liang, J. B., Abdullah, N., Goh, Y. M., Ebrahimi, R., & Shokryazdan, P. (2016). Extraction and characterization of oligosaccharides from palm kernel cake as prebiotic. *BioResources, 11*(1), 674-695. doi:10.15376/biores.11.1.674-695

Jia, W., Mikulski, D., Rogiewicz, A., Zduńczyk, Z., Jankowski, J., & Slominski, B. A. (2012). Low-fiber canola. Part 2. Nutritive value of the meal. *Journal of Agricultural and Food Chemistry, 60*(50), 12231-12237. doi:10.1021/jf302118c

Jiang, Z., Zhou, Y., Lu, F., Han, Z., & Wang, T. (2008). Effects of different levels of supplementary alpha-amylase on digestive enzyme activities and pancreatic amylase mRNA expression of young broilers. *Asian-Australasian Journal of Animal Sciences, 21*(1), 97-102. doi:10.5713/ajas.2008.70110

Jin, L. Z., Ho, Y. W., Abdullah, N., & Jalaludin, S. (2000). Digestive and bacterial enzyme activities in broilers fed diets supplemented with Lactobacillus cultures. *Poultry Science, 79*(6), 886-891. doi:10.1093/ps/79.6.886

Jørgensen, H., Zhao, X. Q., & Eggum, B. O. (1996). The influence of dietary fibre source and level on the development of the gastrointestinal tract, digestibility and energy metabolism in broiler chickens. *British Journal of Nutrition, 75*(03), 379-379. doi:10.1079/BJN19960141

Kalmendal, R., Elwinger, K., Holm, L., & Tauson, R. (2011). High-fibre sunflower cake affects small intestinal digestion and health in broiler chickens. *British Poultry Science, 52*(1), 86-96. doi:10.1080/00071668.2010.547843

Keshavarz, K. & Fuller, H. (1980). The influence of widely fluctuating temperatures on heat production and energetic efficiency of broilers. *Poultry Science, 59*(9), 2121-2128.

Khin, H. S. (2004). *Evaluation of solid state fermentation by aspergillus niger to improve the nutritive value of palm kernel cake of broilers.* (Doctoral dissertation). Universiti Putra Malaysia, Serdang, Malaysia.,

Knudsen, K. E. B., Jensen, B. B., & Hansen, I. (1993). Digestion of polysaccharides and other major components in the small and large intestine of pigs fed on diets consisting of oat fractions rich in β-D-glucan. *British Journal of Nutrition, 70*(2), 537-556.

Koelkebeck, K. W., Parsons, C. M., & Wang, X. (1998). Effect of acute heat stress on amino acid digestibility in laying hens. *Poultry Science, 77*(9), 1393-1396. doi:10.1093/ps/77.9.1393

Lara, L. J. & Rostagno, M. H. (2013). Impact of heat stress on poultry production. *Animals, 3*(2), 356-369. doi:10.3390/ani3020356

Lawal, T. E., Lyayi, E. A., Adeniyi, B. A., & Adaramoye, O. A. (2010). Biodegradation of palm kernel cake with multienzyme complexes from fungi and its feeding value for broilers. *International Journal of Poultry Science, 9*(7), 695-701. doi:10.3923/ijps.2010.695.701

Le Gall, M., Serena, A., Jørgensen, H., Theil, P. K., & Knudsen, K. E. B. (2009). The role of whole-wheat grain and wheat and rye ingredients on the digestion and fermentation processes in the gut–a model experiment with pigs. *British Journal of Nutrition, 102*(11), 1590-1600.

Leeson, S. & Summers, J. D. (1997). *Poultry Nutrition* (2nd Ed. ed.). Guelph, Ontario, Canada: University books.

Li, Y., Chen, X., Chen, Y., Li, Z., & Cao, Y. (2010). Effects of β-mannanase expressed by Pichia pastoris in corn–soybean meal diets on broiler performance, nutrient digestibility, energy utilization and immunoglobulin levels. *Animal Feed Science and Technology, 159*(1-2), 59-67.

Lim, H.-A., Ng, W.-K., Lim, S.-L., & Ibrahim, C. O. (2001). Contamination of palm kernel meal with Aspergillus flavus affects its nutritive value in pelleted feed for tilapia, Oreochromis mossambicus. *Aquaculture Research, 32*, 895-905.

Livak, K. J. & Schmittgen, T. D. (2001). Analysis of relative gene expression data using real-time quantitative PCR and the 2-ΔΔCT method. *Methods, 25*(4), 402-408. doi:10.1006/meth.2001.1262

Loh, T. C., Choe, D. W., Foo, H. L., Sazili, A. Q., & Bejo, M. H. (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*, 149-149. doi:10.1186/1746-6148-10-149

Loh, T. C., Chong, S. W., Foo, H. L., & Law, F. L. (2009). Effects on growth performance, faecal microflora and plasma cholesterol after supplementation of spray-dried metabolite to postweaning rats. *Czech Journal of Animal Science, 54*(1), 10-16. doi:10.17221/1738-cjas

Londero, A., Peláez, M. A. L., Diosma, G., DeAntoni, G. L., Abrahama, A. G., & Garrote, G. L. (2014). Fermented whey as poultry feed additiveto prevent fungal contamination. *J Sci Food Agric, 94*, 3189-3194.

Longo, F. A., Menten, J. F. M., Pedroso, A. A., Figueiredo, A. N., Racanicci, A. M. C., Gaiotto, J. B., & Sorbara, J. O. B. (2004). Determination of the energetic value of corn, soybean meal and micronized full fat soybean for newly hatched chicks. *Revista Brasileira de Ciência Avícola, 6*(3), 147-151. doi:10.1590/s1516-635x2004000300003

Longstaff, M. & McNab, J. M. (1991). The inhibitory effects of hull polysaccharides and tannins of field beans (Vicia faba L.) on the digestion of amino acids, starch and lipid and on digestive enzyme activities in young chicks. *British Journal of Nutrition, 65*(2), 199-216. doi:10.1079/BJN19910081

Luo, D., Yanga, F., Yang, X., Yao, J., Shi, B., & Zhou, Z. (2009). Effects of xylanase on performance, blood parameters, intestinal morphology, microflora and digestive enzyme activities of broilers fed wheat-based diets. *Asian-Australas J Anim Sci, 22*(9), 1288-1295.

Malaysian Palm Oil Board. (2019). *Overview of the Malaysian Palm Oil Industry 2018*. Ministry of Plantation Industries and Commodities, Malaysian Palm Oil Board. Retrieved from http://palmoilis.mpob.gov.my/V4/wp-content/uploads/2020/03/Overview_of_Industry_2018.pdf

Malaysian Palm Oil Board. (2020). *Production of palm kerne cake 2020*. Ministry of Plantation Industries and Commodities, Malaysian Palm Oil Board. Retrieved from https://bepi.mpob.gov.my/index.php/en/production/production-2020/production-of-palm-kernel-cake-2020

Mardhati, M., Wong, H. K., & 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., & Azahan, E. A. E. (2005). Performance of locally isolated microorganism in degrading palm kernel cake (PKC) fibre and improving the nutritional value of fermented PKC. *Journal of Tropical Agriculture and Food Science, 33*(2), 311-319.

Marsman, G., Gruppen, H., van der Poel, A., Kwakkel, R., Verstegen, M., & Voragen, A. (1997). The effect of thermal processing and enzyme treatments of soybean meal on growth performance, ileal nutrient digestibilities, and chyme characteristics in broiler chicks. *Poultry Science, 76*(6), 864-872. doi:10.1093/ps/76.6.864

Mateos, G. G., Jimenez-Moreno, E., Serrano, M. P., & Lazaro, 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. doi:10.3382/japr.2011-00477

Mateos, G. G. & Sell, J. L. (1981). Influence of fat and carbohydrate source on rate of food passage of semipurified diets for laying hens. *Poultry Science, 60*(9), 2114-2119. doi:10.3382/ps.0602114

Mateos, G. G., Sell, J. L., & Eastwood, J. A. (1982). Rate of food passage (transit time) as influenced by level of supplemental fat. *Poultry Science, 61*(1), 94-100. doi:10.3382/ps.0610094

Mathiavanan, R., Selvaraj, P., & Nanjappan, K. (2006). Feeding of fermented soybean meal on broiler performance. *International Journal of Poultry Science, 5*(9), 868-872.

Ministry of Agriculture and Agro-based Industry. (2011). *National Agro Food Policy 2011-2020*. Ministry of Agriculture and Agro-based Industry, Department of Strategic Planning and International.

Ministry of Plantation Industry and Commodities. (2020). *Agricommodity Pocketstats Q4/2020*. Ministry of Plantation Industry and Commodities of Malaysia

Mirnawati, Rizal, Y., Marlida, Y., & Kompiang, I. P. (2011). Evaluation of Palm Kernel Cake Fermented by aspergillus niger as substitute for soybean meal protein in the diet of broiler. *International Journal of Poultry Science, 10*(7), 537-541. doi:10.3923/ijps.2011.537.541

Moharrery, A. & Mohammadpour, A. A. (2005). Effects 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.

Montagne, L., Pluske, J. R., & 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. doi:10.1016/S0377-8401(03)00163-9

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

Muangkeow, N. & 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. & 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.

Murry Jr, A. C., Hinton Jr, A., & Morrison, H. (2004). Inhibition of growth of Escherichia coli, Salmonella typhimurium, and Clostridia perfringens on chicken feed media by Lactobacillus salivarius and Lactobacillus plantarum. *International Journal of Poultry Science, 3*(9), 603-607.

Najafi, P., Zulkifli, I., Jajuli, N. A., Farjam, A. S., Ramiah, S. K., Amir, A. A., . . . Eckersall, D. (2015). Environmental temperature and stocking density effects on acute phase proteins, heat shock protein 70, circulating corticosterone and performance in broiler chickens. *International Journal of Biometeorology, 59*(11), 1577-1583. doi:10.1007/s00484-015-0964-3

Nalle, C. L., Ravindran, V., & Ravindran, G. (2011). Nutritional value of peas (Pisum sativum L.) for broilers: Apparent metabolisable energy, apparent ileal amino acid digestibility and production performance. *Animal Production Science, 51*(2), 150-155. doi:10.1071/AN10100

National Agricultural Statistics Service. (2021). *Prices Received: Corn Prices Received by Month, US*. U.S. Department of Agriculture, National Agricultural Statistics Service. Retrieved from

https://www.nass.usda.gov/Charts_and_Maps/Agricultural_Prices/pricecn.php

National Research Council. (1994). *Nutrient requirements of poultry: Ninth revised edition, 1994*: Washington D.C.: National Academy Press.

Navidshad, B., Liang, J. B., Jahromi, M. F., Akhlaghi, A., & Abdullah, N. (2016). Effects of enzymatic treatment and shell content of palm kernel expeller meal on performance, nutrient digestibility, and ileal bacterial population in broiler chickens. *Journal of Applied Poultry Research, 25*(4), 474-482. doi:10.3382/japr/pfw029

Ng, W.-K., Lim, H.-A., Lim, S.-L., & Ibrahim, C.-O. (2002). Nutritive value of palm kernel meal pretreated with enzyme or fermented with Trichoderma koningii(Oudemans) as a dietary ingredient for red hybrid tilapia (Oreochromis sp.). *Aquaculture Research, 33*, 1199-1207.

Ngopayou, N. J. D. (1984). Nutritional value of palm kernel cake in broiler diets. *Poultry Science, 63*(Suppl 1), 155-156.

Noraini, S., Vikineswary, S., Jaafar, D. M., Azizul, I., Ahmad, A., & Poovasagam, S. (2004). *Biosynthesis of β-mannanase from Aspergillus niger by solid substrate fermentation (SSF) using palm kernel cake (PKC) as the basis of solid substrate.* Paper presented at the Proceedings of International Seminar on Solid State Fermentation., Penang, Malaysia.

Nwokolo, E. N., Bragg, D. B., & Kitts, W. D. (1976). The availability of amino acids from palm kernel, soybean, cottonseed and rapeseed meal for the growing chick. *Poultry Science, 55*(6), 2300-2304. doi:10.3382/ps.0552300

Nwokolo, E. N., Bragg, D. B., & Saben, H. S. (1977). Nutritive evaluation of palm kernel meal for use in poultry rations. *Tropical science, 19*, 147-154.

Odetallah, N., Ferket, P., Grimes, J., & McNaughton, J. (2002). Effect of mannan-endo-1, 4-beta-mannosidase on the growth performance of turkeys fed diets containing 44 and 48% crude protein soybean meal. *Poultry Science, 81*(9), 1322-1331.

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

Olomu, J. M. (1995). Monogastric animal nutrition: Principles and practice. 112-118.

Olubodun, J., Zulkifli, I., Hair-Bejo, M., Kasim, A., & Soleimani, A. F. (2015). Physiological response of glutamine and glutamic acid supplemented

broiler chickens to heat stress. *European Poultry Science, 79*, 1-12. doi:10.1399/eps.2015.87

Onwudike, O. C. (1986). 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*, 187-194.

Osei, S. A. & Amo, J. (1987). Research note: palm kernel cake as a broiler feed ingredient. *Poultry Science, 66*(11), 1870-1873.

Panigrahi, S. & 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. doi:10.1016/0377-8401(94)90190-2

Pinheiro, D. F., Cruz, V. C., Sartori, J. R., & Vicentini Paulino, M. L. M. (2004). Effect of early feed restriction and enzyme supplementation on digestive enzyme activities in broilers. *Poultry Science, 83*(9), 1544-1550. doi:10.1093/ps/83.9.1544

Pranoto, Y., Anggrahini, S., & Efendi, Z. (2013). Effect of natural and Lactobacillus plantarum fermentation on in-vitro protein and starch digestibilities of sorghum flour. *Food Bioscience, 2*, 46-52. doi:10.1016/j.fbio.2013.04.001

Puvača, N., Kostadinović, L., Ljubojević, D., Lukač, D., Lević, J., Popović, S., . . . Đuragić, O. (2015). Effect of garlic, black pepper and hot red pepper on productive performances and blood lipid profile of broiler chickens. *European Poultry Science, 79*, 1-13. doi:10.1399/eps.2015.73

Qureshi, A. A., Din, Z. Z., Abuirmeileh, N., Burger, W. C., Ahmad, Y., & Elson, C. E. (1983). Suppression of avian hepatic lipid metabolism by solvent extracts of garlic: impact on serum lipids. *J Nutr, 113*(9), 1746-1755. doi:10.1093/jn/113.9.1746

Rahim, F., Sabrina, Rusmawati, & 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.

Ramiah, S. K., Abdullah, N., Akhmal, M., Mookiah, S., Farjam, A. S., Wei Li, C., . . . Idrus, Z. (2019). Effect of feeding less shell, extruded and enzymatically treated palm kernel cake on expression of growth-related genes in broiler chickens. *Italian Journal of Animal Science, 18*(1), 997-1004. doi:10.1080/1828051X.2019.1589393

Ramin, M., Alimon, A. R., & Ivan, M. (2010). Effects of fungal treatment on the in vitro digestion of palm kernel cake. *Livestock Research for Rural Development, 22*(82). Retrieved from http://www.lrrd.org/lrrd22/4/rami22082.htm

Ravindran, V., Kornegay, E. T., & Webb, K. E. (1984). Effects of fiber and virginiamycin on nutrient absorption, nutrient retention and rate of passage in growing swine. *Journal of Animal Science, 59*(2), 400-408. doi:10.2527/jas1984.592400x

Regnault, T. R. H., De Vrijer, B., & Battaglia, F. C. (2002). Transport and metabolism of amino acids in placenta. *Endocrine, 19*(1), 23-41. doi:10.1385/ENDO:19:1:23

Rezaei, S., Faseleh Jahromi, M., Liang, J. B., Zulkifli, I., Farjam, A. S., Laudadio, V., & Tufarelli, V. (2015). Effect of oligosaccharides extract from palm kernel expeller on growth performance, gut microbiota and immune response in broiler chickens. *Poultry Science, 94*(10), 2414-2420. doi:10.3382/ps/pev216

Rivas, F. M. & Firman, J. D. (1994). The influence of energy and protein on turkeys during the finisher period. *Journal of Applied Poultry Research, 3*(4), 327-335. doi:10.1093/japr/3.4.327

Robinson, T. & Nigam, P. (2003). Bioreactor design for protein enrichment of agricultural residues by solid state fermentation. *Biochemical Engineering Journal, 13*(2-3), 197-203.

Robinson, T., Singh, D., & Nigam, P. (2001). Solid-state fermentation: a promising microbial technology for secondary metabolite production. *Applied Microbiology and Biotechnology, 55*(3), 284-289.

Rochell, S. J., Applegate, T. J., Kim, E. J., & Dozier, W. A. (2012). Effects of diet type and ingredient composition on rate of passage and apparent ileal amino acid digestibility in broiler chicks. *Poultry Science, 91*, 1647-1653. doi:10.3382/ps.2012-02173

Rodehutscord, M., Timmler, R., & Dieckmann, A. (2002). Effect of L-carnitine supplementation on utilisation of energy and protein in broiler chicken fed different dietary fat levels. *Archiv fur Tierernahrung, 56*(6), 431-441. doi:10.1080/00039420215637

Röder, P. V., Geillinger, K. E., Zietek, T. S., Thorens, B., Koepsell, H., & Daniel, H. (2014). The role of SGLT1 and GLUT2 in intestinal glucose transport and sensing. *PLoS ONE, 9*(2), 20-22. doi:10.1371/journal.pone.0089977

Roslan, M. A. H. (2019). *Enhancing nutritive value of palm kernel expeller through physical treatments for use as poultry feed ingredient.* (Doctoral dissertation). Universiti Putra Malaysia, Serdang, Malaysia,

Roslan, M. A. H., Abdullah, N., Abdul Murad, N. Z., Halmi, M. I. E., Zulkifli, I., & Mustafa, S. (2017). Optimisation of extrusion for enhancing the nutritive value of palm kernel cake using response surface methodology. *BioResources, 12*(3), 6679-6697.

Roslan, M. A. H., Abdullah, N., & Mustafa, S. (2015). Removal of shells in palm kernel cake via static cling and electrostatic separation. *Journal of Biochemistry, Microbiology, and Biotechnology, 3*(1), 1-6.

Saenphoom, P., Liang, J. B., Ho, Y. W., Loh, T. C., & 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. doi:10.5897/AJB11.1211

Saenphoom, P., Liang, J. B., Ho, Y. W., Loh, T. C., & 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. doi:10.5713/ajas.2012.12463

Saleh, A. A., El-Far, A. H., Abdel-Latif, M. A., Emam, M. A., Ghanem, R., & El-Hamid, H. S. A. (2018). Exogenous dietary enzyme formulations improve growth performance of broiler chickens fed a low-energy diet targeting the intestinal nutrient transporter genes. *PLoS ONE, 13*(5), 1-17.

Sanz, M., Flores, A., & Lopez-Bote, C. J. (2000). The metabolic use of energy from dietary fat in broilers is affected by fatty acid saturation. *British Poultry Science, 41*(1), 61-68. doi:10.1080/00071660086411

SAS. (2005). SAS/STAT Software. Cary, NC, USA: SAS Inst. Inc.

Savory, C. J. (1986). Influence of ambient temperature on feeding activity parameters and digestive function in domestic fowls. *Physiology and Behavior, 38*(3), 353-357. doi:10.1016/0031-9384(86)90106-X

Saw, H. Y., Janaun, J., Kumaresan, S., & Chu, C. M. (2012). Characterization of the physical properties of palm kernel cake. *International journal of food properties, 15*(3), 536-548.

Schiavone, A., Dabbou, S., De Marco, M., Cullere, M., Biasato, I., Biasibetti, E., . . . Gasco, L. (2018). Black soldier fly larva fat inclusion in finisher broiler chicken diet as an alternative fat source. *Animal, 12*(10), 2032-2039. doi:10.1017/S1751731117003743

Schneeman, B. O. & Gallaher, D. (1980). Changes in small intestinal digestive enzyme activity and bile acids with dietary cellulose in rats. *The Journal of Nutrition, 110*(3), 584-590. doi:10.1093/jn/110.3.584

Shakouri, M. D., Iji, P. A., Mikkelsen, L. L., & Cowieson, A. J. (2009). Intestinal function and gut microflora of broiler chickens as influenced by cereal grains and microbial enzyme supplementation. *Journal of Animal Physiology and Animal Nutrition, 93*(5), 647-658. doi:10.1111/j.1439-0396.2008.00852.x

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.

Shastak, Y., Ader, P., Feuerstein, D., Ruehle, R., & Matuschek, M. (2019). ß-Mannan and mannanase in poultry nutrition. *World's Poultry Science Journal, 71*(1), 161-174. doi:10.1017/s0043933915000136

Short, F. J., Gorton, P., Wiseman, J., & Boorman, K. N. (1996). Determination of titanium dioxide added as an inert marker in chicken digestibility studies. *Animal Feed Science and Technology, 59*(4), 215-221. doi:10.1016/0377-8401(95)00916-7

Sieo, C. C., Abdullah, N., Tan, W. S., & Ho, Y. W. (2005). Influence of β-glucanase-producing lactobacillus strains on intestinal characteristics and feed passage rate of broiler chickens. *Poultry Science, 84*, 734-741. doi:10.1093/ps/84.5.734

Siri, P. W. & Krauss, R. M. (2005). Influence of dietary carbohydrate and fat on LDL and HDL particle distributions. *Current Atherosclerosis Reports, 7*(6), 455-459. doi:10.1007/s11883-005-0062-9

Soleimani, A. F., Kasim, A., Alimon, A. R., Meimandipour, A., & Zulkifli, I. (2010). Ileal endogenous amino acid flow of broiler chickens under high ambient temperature. *Journal of Animal Physiology and Animal Nutrition, 94*(5), 641-647. doi:10.1111/j.1439-0396.2009.00951.x

Soleimani, A. F., Zulkifli, I., Hair-Bejo, M., Omar, A. R., & Raha, A. R. (2012). The role of heat shock protein 70 in resistance to Salmonella enteritidis in broiler chickens subjected to neonatal feed restriction and thermal stress. *Poultry Science, 91*(2), 340-345. doi:10.3382/ps.2011-01703

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). Retrieved from http://www.lrrd.org/lrrd21/3/solt21037.htm

Son, A. R., Hyun, Y., Htoo, J. K., & 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. doi:10.1016/j.anifeedsci.2013.09.015

Sulabo, R. C., Ju, W. S., & 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*, 1391-1399. doi:10.2527/jas2012-5281

Sumarsih, S., Yudiarti, T., Utama, C. S., Rahayu, E. S., & Harmayani, E. (2010). The influence of using fish fermented by lactic acid bacteria as feed substitution on serum lipid profile of broilers. *Journal of the Indonesian*

Tropical Animal Agriculture, 35(2), 124-128. doi:10.14710/jitaa.35.2.124-128

Summers, J., Spratt, D., & Atkinson, J. (1990). Restricted feeding and compensatory growth for broilers. *Poultry Science, 69*(11), 1855-1861.

Sun, X., Zhang, H., Sheikhahmadi, A., Wang, Y., Jiao, H., Lin, H., & Song, Z. (2015). Effects of heat stress on the gene expression of nutrient transporters in the jejunum of broiler chickens (Gallus gallus domesticus). *International Journal of Biometeorology, 59*(2), 127-135. doi:10.1007/s00484-014-0829-1

Sundu, B. & Dingle, J. (2003). Use of enzymes to improve the nutritional value of palm kernel meal and copra meal. *Proceedings of Quensland Poultry Science Symposium, 1*(14), 1-15.

Sundu, B., Kumar, A., & Dingle, J. (2004). *Comparison between two mannan–degrading enzyme products inclusion in the diet containing increasing level of palm kernel meal*.

Sundu, B., Kumar, A., & Dingle, J. (2005a). *Comparison of feeding values of palm kernel meal and copra meal for broilers.* Paper presented at the Recent Advances in Animal Nutrition in Australia.

Sundu, B., Kumar, A., & Dingle, J. (2005b). *Response of birds fed increasing levels of palm kernel meal supplemented with different enzymes.* Paper presented at the Proceedings of the 17th Australian Poultry Science Symposium, Sydney, New South Wales, Australia, 7-9 February 2005.

Sundu, B., Kumar, A., & Dingle, J. (2006). Palm kernel meal in broiler diets : effect on chicken performance and health. *World's Poultry Science Journal, 62*(June), 316-325. doi:10.1079/WPS2005100

Szczurek, W. (2009). Standardized ileal digestibility of amino acids from several cereal grains and protein-rich feedstuffs in broiler chickens at the age of 30 days. *Jourrnal of Animal and Feed Sciences, 18*(2009), 662-676.

Tan, W. L. (2016). *Fermentation of palm kernel cake by indigenous lactic acid bacteria as potential poultry feed ingredients.* (Master's thesis). Universiti Putra Malaysia, Serdang, Malaysia,

Tang, T. S. & Teoh, P. K. (1985). Palm kernel oil extraction-The malaysian experience. *Journal of the American Oil Chemists' Society, 62*(2), 254-258.

Teng, P. Y. & Kim, W. K. (2018). Review: Roles of Prebiotics in Intestinal Ecosystem of Broilers. *Front Vet Sci, 5*, 245. doi:10.3389/fvets.2018.00245

Wallis, I. R. & Balnave, D. (1984). The influence of environmental temperature, age and sex on the digestibility of amino acids in growing broiler chickens. *British Poultry Science, 25*(3), 401-407. doi:10.1080/00071668408454880

Walugembe, M., Rothschild, M. F., & Persia, M. E. (2015). Effects of high fiber ingredients on the performance , metabolizable energy and fiber digestibility of broiler and layer chicks. *Animal Feed Science and Technology, 188*(2014), 46-52. doi:10.1016/j.anifeedsci.2013.09.012

Wan Zahari, M. & Alimon, A. R. (2004). Use of palm kernel cake and oil palm by-products in compound feed. *Palm Oil Developments, 40*, 5-9. Retrieved from http://palmoilis.mpob.gov.my/publications/POD/pod40-wan.pdf

Wang, Y. (2009). Prebiotics: Present and future in food science and technology. *Food Research International, 42*(1), 8-12.

Webster, A. J. F. (1983). Nutrition and the thermal environment. *Nutritional physiology of farm animals/[edited by] JAF Rook and PC Thomas*.

Wolfenson, D., Sklan, D., Graber, Y., Kedar, O., Bengal, I., & Hurwitz, S. (1987). Absorption of protein, fatty acids and minerals in young turkeys under heat and cold stress. *British Poultry Science, 28*(4), 739-742. doi:10.1080/00071668708417010

Wu, G., Bryant, M., Voitle, R., & Roland Sr, D. (2005). Effects of β-mannanase in corn-soy diets on commercial leghorns in second-cycle hens. *Poultry Science, 84*(6), 894-897.

Xu, Z. R., Hu, C. H., Xia, M. S., Zhan, X. A., & Wang, M. Q. (2003). Effects of dietary fructooligosaccharide on digestive enzyme activities, intestinal microflora and morphology of male broilers. *Poultry Science, 82*(11), 1030-1036. doi:10.1093/ps/83.11.1868

Yaghobfar, A. & Kalantar, M. (2017). Effect of non-starch polysaccharide (NSP) of wheat and barley supplemented with exogenous enzyme blend on growth performance, gut microbial, pancreatic enzyme activities, expression of glucose transporter (SGLT1) and mucin producer (MUC2) genes of broiler chickens. *Revista Brasileira de Ciência Avícola, 19*(4), 629-638. doi:10.1590/1806-9061-2016-0441

Yamauchi, K.-e., Nakamura, E., & Isshiki, Y. (1993). Development with the of the intestinal epithelial villi cell associated increased in chickens mitosis. *Animal Science Technology, 64*(4), 340-350.

Yang, Y., Iji, P. A., Kocher, A., Mikkelsen, L. L., & Choctt, M. (2007). Effects 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. doi:10.1093/japr/16.2.280

Yason, C. V., Summers, B. A., & Schat, K. A. (1987). Pathogenesis of rotavirus infection in various age groups of chickens and turkeys: Pathology. *American Journal of Veterinary Research, 48*(6), 927-938. Retrieved from http://europepmc.org/abstract/MED/3605809

Yeong, S. W. (1983). Amino acids availability of palm kernel cake, palm oil sludge and sludge fermented product (Prolima) in studies with chickens. *MARDI Research Bulletin, 11*(1), 84-88.

Yeong, S. W. (1985, 5-6 Nov 1985). *Palm oil by-products as feeds for poultry.* Paper presented at the National Symposium on Oil Palm By-products for Agro-based Industries., Kuala Lumpur.

Yokhana, J. S., Parkinson, G., & Frankel, T. L. (2016). Effect of insoluble fiber supplementation applied at different ages on digestive organ weight and digestive enzymes of layer-strain poultry. *Poultry Science, 95*(3), 550-559. doi:10.3382/ps/pev336

Zhu, H. L., Hu, L. L., Hou, Y. Q., Zhang, J., & Ding, B. Y. (2014). The effects of enzyme supplementation on performance, digestive parameters of broilers fed corn-soybean diets. *International Journal of Poultry Science, 93*, 1704-1712. doi:10.3382/ps.2013-03626

Zulkifli, I., Ginsos, J., Liew, P. K., & Gilbert, J. (2003). Growth performance and Newcastle disease antibody titres of broiler chickens fed palm-based diets and their response to heat stress during fasting. *Archiv fur Geflugelkunde, 67*(3), 125-130.

Zulkifli, I., Iman Rahayu, H. S., Alimon, A. R., Vidyadaran, M. K., & Babjee, S. A. (2009). Gut microflora and intestinal morphology of commercial broiler chickens and Red Jungle Fowl fed diets containing palm kernel meal. *Archiv fur Geflugelkunde, 73*(1), 49-55.

Zuprizal, Larbier, M., Chagneau, A. M., & Geraert, P. A. (1993). Influence of ambient temperature on true digestibility of protein and amino acids of rapeseed and soybean meals in broilers. *Poultry Science, 72*, 289-295.

BIODATA OF STUDENTS

The student, Muhamad Hakim Mohd Ali Hanafiah was born on 27th April 1991 in Subang Jaya, Selangor. He completed his secondary education at Sekolah Menengah Kebangsaan Agama Pedas, Negeri Sembilan in 2008. He then continued for Foundation Studies in Agricultural Science at the Centre of Foundation Studies for Agricultural Sciences, Universiti Putra Malaysia in 2009. In 2015 he obtained his first degree in Bachelor of Agriculture (Animal Science), Universiti Putra Malaysia. In April 2015, he has been offered the position of research assistant in Universiti Putra Malaysia for 4 months under the supervision of Assoc. Prof. Dr. Azhar Kasim at the Department of Animal Science, Faculty of Agriculture. Later, he pursued his master's degree program at Institute of Tropical Agriculture and Food Security, Universiti Putra Malaysia under the supervision of Prof. Dato' Dr. Zulkifli Idrus. Within two years, he was offered for conversion of study programme to PhD. He is married and granted with two sons.

LIST OF PUBLICATIONS

Hanafiah, H.A., Zulkifli, I., Soleimani, A.F. and Awad, E.A., 2017. Apparent metabolisable energy and ileal crude protein digestibility of various treated palm kernel cake based diets for heat-stressed broiler chickens. Archiv für Geflügelkunde, 81.

Hakim, A.H., Zulkifli, I., Soleimani, A.F., Awad, E.A., Abdullah, N., Chen, W.L. and Mohamad, R., 2020. Passage time, apparent metabolisable energy and ileal amino acids digestibility of treated palm kernel cake in broilers under the hot and humid tropical climate. Italian Journal of Animal Science, 19(1), pp.194-202.