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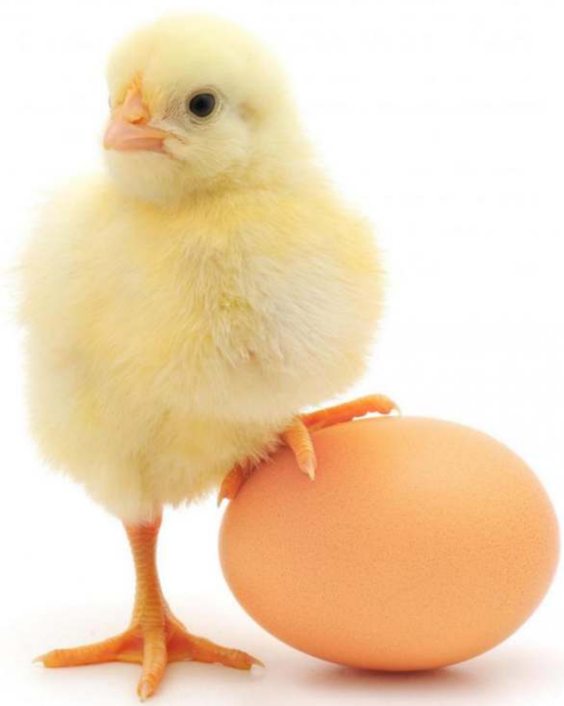

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Research Article
Effect of Dietary Palm Kernel Meal Supplementation on Growth Performance, Blood Metabolites, Microbial Population and Carcass Characteristics of Growing-Meat Quails

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Abstract
Background and Objectives: This study aimed to investigate the effects of palm kernel meal (PKM) supplementation on the growth performance, blood metabolites, gut microbiota and carcass characteristics of growing-meat quails. **Materials and Methods:** A total of 480 male growing-meat quails (21-42 days old) were randomly assigned to 4 treatment groups of 120 quails each. Four treatments were randomly assigned to five replicates each in a completely randomized design. The four treatments were basal diet without PKM supplementation (CON), basal diet with 4% PKM (PKM4), basal diet with 8% PKM (PKM8) and basal diet with 12% PKM (PKM12). **Results:** The final body weight and body weight gain were higher in the PKM4 group than the PKM12 group ($p \leq 0.05$). The PKM4 and PKM8 groups showed a linear relationship between the amount of PKM and body weight ($p = 0.014$ and $p = 0.016$, respectively). The uric acid concentration was significantly lower in the PKM4 than in the other treatment groups ($p \leq 0.05$). The relative weight of eviscerated carcasses increased in the PKM8 group ($p \leq 0.05$). The PKM8 group also had a higher thymus weight than the CON group ($p \leq 0.05$). Moreover, PKM supplementation significantly decreased the number of *Salmonella enteritidis* and *Escherichia coli* and significantly increased the number of *Lactobacillus* spp. **Conclusion:** Growing-meat quails that received a diet supplemented with 8% PKM showed improvements in growth performance, protein utilization, relative carcass and thymus weights and gut microflora, with no hepatic damage.

Key words: Blood metabolite, growing-meat quail, growth performance, gut microbiota, palm kernel meal

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The number of Japanese quail (*Coturnix coturnix japonica*) has gradually increased because they can be used for egg and meat consumption. To meet consumer demand, many researchers have focused on improving quail performance by genetic selection[1] and diet manipulation[2]. However, the quail industry in Thailand is facing the challenge of expensive feed ingredients. Palm kernel meal (PKM) has been suggested as a potential alternative feed ingredient because of its reasonable price and accessibility. The PKM has been shown to significantly increase *Salmonella* colonization in broilers[3]. Studies have demonstrated that PKM could act as an effective prebiotic in modulating gut health by reducing intestinal pathogens[4]. Furthermore, the PKM has been shown to improve growth performance, immunoglobulin A and gut microflora and to reduce the occurrence of *Clostridium* spp. and *Salmonella* spp.[5]. The inclusion level of the PKM up to 16% also increased the body weight gain of broilers[6]. However, decreased growth performance and feed efficiency were observed in young chicks fed with 30% PKM[7]. The PKM contains higher amounts of non-starch polysaccharides, mostly in the form of β-mannan[8]. The PKM supplementation increased digesta viscosity, which resulted in lower nutrient digestibility[9]. Many studies have examined the effects of PKM supplementation on broiler chickens and laying hens but there is limited information on its use in growing-meat quails. This study hypothesized that an appropriate level of the PKM would has beneficial effects on growth and promote quail performance. Therefore, the present study was sought to investigate how dietary supplementation with PKM affected the growth performance, blood metabolites and carcass characteristics of growing-meat quails between 21 and 42 days of age.

MATERIALS AND METHODS

Birds, management and experimental design: Male growing-meat quails at 21 days of age were obtained from a domestic farm (Weerapong Chareon Quail's Farm, Angthong Province, Thailand). The quails were individually weighed before being placed into cages. There were 24 birds in each cage and they were placed according to a completely randomized design. Each cage was equipped with a feeder and a water-delivery system that was 45 cm wide×90 cm long. The lighting schedule was controlled with a 23 h photoperiod (23L:1D) throughout the experimental period. Experimental diets were formulated to meet or exceed the nutrient recommendations[10] for growing quails (Table 1) and were fed to the birds from 21-42 days of age. The quails had free access to feed and water during the entire experimental period. The temperature of the quails' house ranged from 33-35°C, which was an open-house system. The Animal Care and Use Committee of the National Research Council of Thailand approved all procedures for the care and handling of the growing quails.

Four hundred eighty male growing quails were randomly assigned to four treatment groups. There were 24 quails per cage and experiments were replicated 5 times. The diet treatment groups were control (basal diet without PKM supplementation; CON), basal diet+4% PKM (PKM4), basal diet+8% PKM (PKM8) and basal diet+12% PKM (PKM12). The nutrient composition of PKM was performed following the standard guideline[11] and presented in Table 2.

Growth performance: Quail body weight (BW) was recorded at the beginning and end of the experiment so that body weight gain (BWG) could be calculated. On day 42, the residual feed in each cage was weighed using an automatic weighing machine to measure feed intake and to calculate the feed conversion ratio (FCR).

Blood collection and analyses: At the termination of the experiment on day 42, the feed was removed from the quail cages 3 h before blood collection. Three quails from each cage (15 quails per treatment) were randomly selected for blood collection through the jugular vein. Samples were transferred to a syringe with and without anticoagulant and then centrifuged at 3,000 g at 4°C for 10 min to separate the serum and plasma. The samples were immediately analyzed using enzymatic methods to quantify uric acid, glucose, aspartate aminotransferase (AST), total cholesterol (TC) and triglyceride concentrations. Samples were analyzed in triplicate. All procedures were performed according to the manufacturers' instructions.

Relative carcass and immune organ weights: After blood collection, three growing quails from each cage were weighed immediately and then sacrificed by cervical dislocation. The head, giblets, intestines and feet were removed before reweighing and the weights of the liver, leg, breast muscle, bursa of Fabricius, spleen and thymus were obtained. These weight data were used to calculate the carcass composition, expressed as a percentage of live BW.

Microbial population: Fecal samples were collected from 60 quails (15 birds per treatment) at 42 days of age and

Table 1: Ingredients and nutrient composition of basal diets (% as-fed basis)

Ingredients	CON	PKM4	PKM8	PKM12
Corn	50.02	46.81	43.89	42.66
Soybean meal (45%)	39.96	38.18	35.99	30.76
Palm kernel meal	0.00	4.00	8.00	12.00
Corn gluten meal	3.53	4.00	4.70	7.46
Soybean oil	3.06	3.58	3.99	3.69
L-lysine sulfate (78%)	0.17	0.17	0.17	0.17
DL-methionine (98%)	0.10	0.10	0.10	0.10
Monodicalcium phosphate	1.24	1.24	1.24	1.24
Limestone	1.30	1.30	1.30	1.30
Salt	0.25	0.25	0.25	0.25
Vitamin-mineralpremix[1]	0.37	0.37	0.37	0.37
Total	100.00	100.00	100.00	100.00
Calculated composition[2]				
Metabolisable energy (kcal kg^{-1})	2.90	2.90	2.90	2.90
Crude protein (%)	24.00	24.00	24.00	24.00
Lysine (%)	1.30	1.30	1.30	1.30
Methionine+cystine (%)	0.75	0.75	0.75	0.75
Threonine (%)	1.02	1.02	1.02	1.02
Calcium (%)	0.80	0.80	0.80	0.80
Available phosphorus (%)	0.30	0.30	0.30	0.30
Analyzed values (%)				
Crude protein	23.72	23.04	23.46	23.83
Crude fat	4.62	4.37	4.64	4.58
Moisture	9.92	9.64	9.33	9.21
Ash	4.12	4.57	4.24	4.43

CON: Control (basal diet), PKM4: Basal diet +4% PKM, PKM8: Basal diet +8% PKM and PKM12 basal diet +12% PKM. [1]Provided per kilogram of diet: Vitamin A (retinyl acetate): 8,000 IU, Vitamin D_3 (cholecalciferol): 1,600 IU, Vitamin E (DL-α-tocopheryl acetate): 60 mg, Vitamin B_{12} (cyanocobalamin): 0.02 mg, Vitamin K: 3 mg, Vitamin B_2: 8 mg, Vitamin B_6: 4 mg, Niacin: 60 mg, Folic acid: 2 mg, Pantothenic acid: 20 mg, $ZnSO_4$: 118 mg, $MnSO_4.H_2O$: 116 mg, $CuSO_4$: 33 mg, Na_2SeO_3: 0.8 mg and $FeSO_4.H_2O$: 60 mg, [2]Calculated values (% as-fed basis)

Table 2: Proximate analysis of palm kernel meal[1]

Items	Amounts
Crude protein (%)	16.430
Crude fat (%)	8.420
Crude fiber (%)	18.120
Metabolisable energy (kcal kg^{-1})	2.421
Calcium (%)	0.260
Total phosphorus (%)	0.570
Available phosphorus (%)	0.190
Ash (%)	4.310
Moisture (%)	8.740

[1]Analysis values (% as-fed basis)

used for microbial enumeration. Briefly, 1 g fresh fecal samples were directly transferred into 15 mL MacCartney tubes, diluted in saline solution and resuspended by vortex mixing. Each dilution was poured onto the surface of an agar plate in triplicate using *S. enteritidis* agar, Lactobacillus MRS broth and MacConkey agar (Difco, Laboratories, Detroit, MI). All plates were immediately incubated at 37 for 24 h in an anaerobic cabinet. The presence of microbial growth was detected by colony counter (Selby, Model SCC100, Sydney, Australia).

Statistical analysis: The data were analyzed using the general linear model procedure in the statistical software package, SAS (SAS Institute, Inc., Cary, NC, USA). Each quail cage was defined as the experimental unit for detecting growth performance, whereas the selected quails were considered as the experimental unit for blood metabolite quantities, gut microbiota, carcass and immune organ weights. Statistically significant differences among dietary treatments were determined by Duncan's new multiple range test at a probability level of $p \leq 0.05$, while a probability level from >0.05 to <0.10 was defined as a tendency.

RESULTS AND DISCUSSION

Growth performance: Table 3 shows that there were no significant differences in initial BW, feed intake and FCR among the four dietary treatments. The PKM4 and PKM8 diets significantly improved the final BW and BWG of the quails at six weeks ($p \leq 0.05$). However, the PKM12 diet had detrimental effects, especially on the final BW and BWG, compared with the other treatments ($p \leq 0.05$). Linear reductions in final BW ($p = 0.014$) and BWG ($p = 0.016$) were observed as the level of PKM increased. There was also a tendency for the FCR to increase with the level of PKM ($p = 0.084$). The greatest benefit of PKM supplementation in modulating the weight gain of broilers was observed in the PKM8 group. This is in agreement

Table 3: Effects of dietary palm kernel meal supplementation on the growth performance of growing-meat quails aged 21-42 days[1]

						p-value	
Items	CON	PKM4	PKM8	PKM12	SEM[2]	Linear	Quadratic
Initial BW (g bird^{-1})	71.29	72.35	72.36	72.33	0.536	0.538	0.647
Final BW (g bird^{-1})	153.83[a]	156.42[a]	150.83[ab]	139.92[b]	2.153	0.014	0.279
Body weight gain (g bird^{-1})	82.54[a]	84.06[a]	78.47[ab]	67.59[b]	0.267	0.016	0.269
Feed intake (g bird^{-1})	349.00	371.00	375.00	338.00	8.423	0.698	0.637
FCR (feed:gain)[3]	4.31	4.43	4.82	5.04	0.163	0.084	0.591

CON: Control (basal diet), PKM4: Basal diet +4% PKM, PKM8: Basal diet +8% PKM and PKM12 basal diet +12% PKM. [1]Least square means of five cages per treatment with twenty-four quails each. [2]SEM: Standard error of the mean. [3]FCR: Feed conversion ratio. [ab]Means in the same row that do not share the same superscript indicate a significant difference ($p \leq 0.05$)

Table 4: Effects of dietary palm kernel meal supplementation on blood metabolites of growing-meat quails[1]

						p-value	
Items (mg dL^{-1})	CON	PKM4	PKM8	PKM12	SEM[2]	Linear	Quadratic
Uric acid	5.67[a]	3.33[b]	6.79[a]	6.73[a]	0.541	0.057	0.116
Glucose	210.20	234.20	216.60	206.80	7.461	0.641	0.595
AST	350.80	329.20	348.00	426.40	17.015	0.099	0.373
TC	129.66	121.47	125.20	122.68	23.089	0.566	0.427
TG	986.31	994.88	967.21	963.97	17.890	0.576	0.944

CON: Control (basal diet), PKM4: Basal diet +4% PKM, PKM8: Basal diet +8% PKM and PKM12 basal diet +12% PKM. [1]Values are mean of 10 growing-meat quails per treatment. [2]SEM: Standard error of the mean. [3]AST: Aspartate aminotransferase, TC: Total cholesterol, TG: Triglyceride. [ab]Means in the same row that do not share the same superscript indicate a significant difference ($p \leq 0.05$)

with previous studies[6,12], which showed that young birds were capable of using small amounts of PKM without detrimental effects on their performance. Furthermore, the improvement in broilers with small amounts of PKM supplementation has been attributed to the full development of the digestive system of the birds after two weeks[13], which is consistent with the present study. Low levels of supplementation had a positive influence on bird performance by promoting microbial activity, nutrient digestion and absorption and gastrointestinal development[14,15]. However, dietary supplementation with PKM12 resulted in a decreased final BW and BWG. Research has shown that PKM contains higher amounts of non-starch polysaccharide (NSP), especially β-mannan[8], which accounts for approximately 494 g kg^{-1} of acid detergent fiber and 779 g kg^{-1} of neutral detergent fiber[16]. These specific components might have caused the observed inhibitory effects on nutrient usage in quails because the birds were sensitive to the high levels of soluble and insoluble NSP with 12% PKM supplementation.

Blood metabolites: As shown in Table 4, the addition of PKM to the diet of growing-meat quails had no effects on glucose, aspartate aminotransferase, cholesterol and triglyceride concentrations. However, the concentration of uric acid was significantly lower in the PKM4 quails compared with other treatments. Furthermore, the quails that consumed PKM at levels greater than 4% tended to reduce protein usage by increasing the uric acid concentration ($p = 0.057$). It is unclear how PKM supplementation modulates protein usage but it may be associated with microbial fermentation. Published data show that feeding birds fiber positively enhances microbial fermentation in the hind gut[17], which subsequently improves protein digestibility[18] and changes digestive enzyme activities and amino acid absorption[18-20]. The present study also found that AST concentrations tended to increase as the level of PKM increased ($p = 0.099$). Increased levels of AST have been found to damage various organs, especially the liver[21]. These results indicate that the addition of 4% PKM in the diet was not harmful to the liver.

Relative carcass weights: The results in Table 5 show that the dietary PKM had no significant effect on the relative weights of the leg muscle, breast or liver of growing meat quails at 42 days of age. The results are consistent with those of a previous investigation[22], which found that growing quails on a diet consisting of 15% PKM for two weeks showed no improvement in leg and breast muscle weights. However, the relative weight of eviscerated carcasses was higher in quails fed the PKM8 diet than in those fed the PKM12 diet ($p \leq 0.05$). In addition, the amount of PKM had a linear effect on carcass weight. As the level of PKM increased, the eviscerated carcass weight decreased ($p = 0.092$). This effect on carcass weight was statistically significant in the quails fed the PKM4 and PKM8 diets, suggesting enhanced nutrient usage that resulted in further accumulation of the nutrients in the organs. However, a previous report demonstrated that increasing the level of PKM to more than 15% in the diets of growing-meat quails had detrimental effects on carcass weight[22], which is consistent with the present study. This result indicates that PKM could be used as an effective ingredient in feed formulations for growing-meat quails to increase carcass composition without enlargement of the liver.

Relative immune organ weights: The lymphoid organ weight of the bursa of Fabricius significantly influences humoral immunity within 24 h of hatching[23], initially leading to a proliferation of B cell development. This study found that the relative weights of the bursa of Fabricius and spleen were unaffected by PKM supplementation compared with control (Table 6). This result is in line with that of a previous report[23], in which PKM supplementation had minimal effects on growing-meat quails after 21 days of age. A linear improvement in relative thymus weight was also observed with increasing PKM supplementation ($p = 0.017$). However, the relative weight of the thymus was greater in the PKM8 group than in the control group ($p \leq 0.05$). Increased lymphoid organ size has been used to identify immune status in quails[24]. The increase in thymus weight with PKM supplementation is not fully understood but may be due to the increase in *Lactobacillus* spp. preventing pathogenic invasion.

Microbial population: As shown in Table 7, supplementation with PKM8 led to significant reductions in *S. enteritidis* and *E. coli* ($p \leq 0.05$) at 42 days compared with the control treatment. There are few reports on the effect of PKM supplement on microbial shedding in growing-meat quails. A previous report showed that mannose and manno-oligosaccharides in PKM could act as prebiotics in chickens[25]. This could change microbial profiles in the gut, which in turn would lead to better metabolic function, immunity and digestion[3,25]. This is in agreement with previous reports that showed that feeding prebiotics derived from NSP promoted gut health by increasing the numbers of *Lactobacillus* and *Bifidobacterium* while decreasing those of pathogens, especially *E. coli* and *Salmonella* spp.[5,25].

Table 5: Effects of dietary palm kernel meal supplementation on carcass characteristics of growing-meat quails[1]

						p-value	
Items	CON	PKM4	PKM8	PKM12	SEM[2]	Linear	Quadratic
Relative carcass weights (g/100 g BW)							
Eviscerated carcass	59.15[a]	57.86[ab]	62.61[a]	50.08[b]	1.744	0.092	0.027
Leg muscle	14.65	14.97	14.57	14.64	0.213	0.834	0.678
Breast muscle	26.91	28.11	27.63	27.87	0.702	0.718	0.630
Liver	2.03	2.04	2.12	2.21	0.093	0.461	0.786

CON: Control (basal diet), PKM4: Basal diet +4% PKM, PKM8: Basal diet +8% PKM and PKM12 basal diet +12% PKM. [1]Values are the means of 15 growing-meat quails per treatment. [2]SEM: Standard error of the mean. [ab]Means in the same row that do not share the same superscript indicate a significant difference ($p \leq 0.05$)

Table 6: Effects of dietary palm kernel meal supplementation on relative immune organ weights of growing-meat quails[1]

						p-value	
Item	CON	PKM4	PKM8	PKM12	SEM[2]	Linear	Quadratic
Relative carcass weights (g/100 g BW)							
Bursa of fabricius	0.094	0.110	0.096	0.104	0.004	0.697	0.206
Spleen	0.070	0.060	0.058	0.072	0.005	0.926	0.836
Thymus	0.106[b]	0.134[a]	0.146[a]	0.128[a]	0.005	0.017	0.441

CON: Control (basal diet), PKM4: Basal diet +4% PKM, PKM8: Basal diet +8% PKM and PKM12 basal diet +12% PKM. [1]Values are the means 15 growing-meat quails per treatment. [2]SEM: Standard error of the mean. [ab]Means in the same row that do not share the same superscript indicate a significant difference ($p \leq 0.05$)

Table 7: Effects of dietary palm kernel meal supplementation on caecal microbial population of growing-meat quails[1]

						p-value	
Items	CON	PKM4	PKM8	PKM12	SEM[2]	Linear	Quadratic
Microbial count ($\log_{10}$ CFU g^{-1} content)							
Salmonella enteritidis	6.79[a]	4.43[b]	4.29[b]	5.01[b]	0.321	0.025	0.112
Lactobacillus spp.	5.89[b]	7.90[a]	8.84[a]	7.94[a]	0.364	0.014	0.337
E. coli	7.21[a]	4.92[b]	4.56[b]	5.81[ab]	0.358	0.127	0.419

CON: Control (basal diet), PKM4: Basal diet +4% PKM, PKM8: Basal diet +8% PKM and PKM12 basal diet +12% PKM. [1]Values are the means of 15 growing-meat quails per treatment. [2]SEM: Standard error of the mean. [ab]Means in the same row that do not share the same superscript indicate a significant difference ($p \leq 0.05$)

CONCLUSION AND FUTURE RECOMMENDATION

The reported effects appear to play an important role in balancing gut microflora and enhancing lymphoid organ weights and thus affected the growth performance. Future research needs to consider other factors that affect the microbial population and immunity of quails when fed a PKM diet.

SIGNIFICANCE STATEMENT

This study found that palm kernel meal supplementation had positive effects on quails by increasing body weight gain, thymus weight and the population of *Lactobacillus* spp., while decreasing the number of *Salmonella enteritidis* and *E. coli*. The findings provide further information for animal nutritionists on the use of local feed ingredients to improve growth performance and gut health. Consequently, a new theory on the benefits of PKM supplementation could be considered.

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REFERENCES

1. Khaldari, M., A. Pakdel, H.M. Yegane, A.N. Javaremi and P. Berg, 2010. Response to selection and genetic parameters of body and carcass weights in Japanese quail selected for 4-week body weight. Poult. Sci., 89: 1834-1841.
2. Donaldson, J., M.T. Madziva and K.H. Erlwanger, 2017. The effects of high-fat diets composed of different animal and vegetable fat sources on the health status and tissue lipid profiles of male Japanese quail (*Coturnix coturnix* Japonica). Asian-Aust. J. Anim. Sci., 30: 700-711.
3. Allen, V.M., F. Fernandez and M.H. Hinton, 1997. Evaluation of the influence of supplementing the diet with mannose or palm kernel meal on salmonella colonisation in poultry. Br. Poult. Sci., 38: 485-488.
4. Ibuki, M., J. Kovacs-Nolan, K. Fukui, H. Kanatani and Y. Mine, 2011. β 1-4 mannobiose enhances *Salmonella*-killing activity and activates innate immune responses in chicken macrophages. Vet. Immunol. Immunopathol., 139: 289-295.
5. Rezaei, S., M.F. Jahromi, J.B. Liang, I. Zulkifli, A.S. Farjam, V. Laudadio and V. Tufarelli, 2015. Effect of oligosaccharides extract from palm kernel expeller on growth performance, gut microbiota and immune response in broiler chickens. Poult. Sci., 94: 2414-2420.
6. Abdollahi, M.R., B.J. Hosking, D. Ning and V. Ravindran, 2016. Influence of palm kernel meal inclusion and exogenous enzyme supplementation on growth performance, energy utilization and nutrient digestibility in young broilers. Asian-Aust. J. Anim. Sci., 9: 539-548.
7. Mardhati, M., H.K. Wong and S. Noraini, 2011. Growth performance and carcass quality of broilers fed with palm kernel meal-based rations. J. Trop. Agric. Food Sci., 39: 157-166.
8. Abdollahi, M.R., B. Hosking and V. Ravindran, 2015. Nutrient analysis, metabolisable energy and ileal amino acid digestibility of palm kernel meal for broilers. Anim. Feed Sci. Technol., 206: 119-125.
9. Navidshad, B., J.B. Liang, M.F. Jahromi, A. Akhlaghi and N. Abdullah, 2016. Effects of enzymatic treatment and shell content of palm kernel expeller meal on performance, nutrient digestibility and ileal bacterial population in broiler chickens. J. Applied Poult. Res., 25: 474-482.
10. NRC., 1994. Nutrient Requirements of Poultry. 9th Edn., National Academy Press, Washington, DC., USA., ISBN-13: 9780309048927, Pages: 155.
11. AOAC., 2000. Official Methods of Analysis. 17th Edn., Association of Official Analytical Chemistry, Arlington, VA., USA.
12. Shakila, S., P.S. Reddy, P.V.V.S. Reddy, J.V. Ramana and A. Ravi, 2012. Effect of palm kernel meal on the performance of broilers. Tamilnadu J. Vet. Anim. Sci., 8: 227-234.
13. Sell, J.L., 1996. Physiological limitations and potential for improvement in gastrointestinal tract function of poultry. J. Applied Poult. Res., 5: 96-101.
14. Yeoman, C.J., N. Chia, P. Jeraldo, M. Sipos, N.D. Goldenfeld and B.A. White, 2012. The microbiome of the chicken gastrointestinal tract. Anim. Health Res. Rev., 13: 89-99.
15. Pan, D. and Z. Yu, 2014. Intestinal microbiome of poultry and its interaction with host and diet. Gut Microbes, 5: 108-119.
16. Almaguer, B.L., R.C. Sulabo, Y. Liu and H.H. Stein, 2014. Standardized total tract digestibility of phosphorus in copra meal, palm kernel expellers, palm kernel meal and soybean meal fed to growing pigs. J. Anim. Sci., 92: 2473-2480.
17. Sadeghi, A., M. Toghyani and A. Gheisari, 2015. Effect of various fiber types and choice feeding of fiber on performance, gut development, humoral immunity and fiber preference in broiler chicks. Poult. Sci., 94: 2734-2743.
18. Shakouri, M.D., P.A. Iji, L.L. Mikkelsen and A.J. Cowieson, 2009. Intestinal function and gut microflora of broiler chickens as influenced by cereal grains and microbial enzyme supplementation. Anim. Physiol. Anim. Nutr., 93: 647-658.
19. Iji, P.A., A.A. Saki and D.R. Tivey, 2001. Intestinal structure and function of broiler chickens on diets supplemented with a mannan oligosaccharide. J. Sci. Food Agric., 81: 1186-1192.

20. Walugembe, M., J.C.F. Hsieh, N.J. Koszewski, S.J. Lamont, M.E. Persia and M.F. Rothschild, 2015. Effects of dietary fiber on cecal short-chain fatty acid and cecal microbiota of broiler and laying-hen chicks. Poult. Sci., 94: 2351-2359.
21. Huang, X.J., Y.K. Choi, H.S. Im, O. Yarimaga, E. Yoon and H.S. Kim, 2006. Aspartate aminotransferase (AST/GOT) and alanine aminotransferase (ALT/GPT) detection techniques. Sensors, 6: 756-782.
22. Makinde, O.J., A.A. Sekoni, S. Babajide, I. Samuel and E. Ibe, 2013. Comparative response of Japanese quails (*Coturnix coturnix* Japonica) fed palm kernel meal and Brewer's dried grain based diets. Int. J. Agric. Biosci., 2: 217-220.
23. Chrząstek, K., J.P. Madej, E. Mytnik and A. Wieliczko, 2011. The influence of antibiotics on B-cell number, percentage and distribution in the bursa of Fabricius of newly hatched chicks. Poult. Sci., 90: 2723-2729.
24. Wang, F.R., X.F. Dong, J.M. Tong, X.M. Zhang, Q. Zhang and Y.Y. Wu, 2009. Effects of dietary taurine supplementation on growth performance and immune status in growing Japanese quail (*Coturnix coturnix* Japonica). Poult. Sci., 88: 1394-1398.
25. Sundu, B., A. Kumar and J. Dingle, 2006. Palm kernel meal in broiler diets: Effect on chicken performance and health. World's Poult. Sci. J., 62: 316-325.