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Enhancing Broilers Performance Fed Palm Kernel Expeller (PKE) Feeds Fortified with Supplements

Muhamad Amin Jahari[1], Muhamad Akhmal Hakim Roslan[2*], Shuhaimi Mustafa[1,3], Norhani Abdullah[2], Zulkifli Idrus[2]

[1]Halal Products Research Institute, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia.
[2]Institute of Tropical Agriculture and Food Security, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia
[3]Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia.

*Corresponding author:
Muhamad Akhmal Hakim Roslan
Institute of Tropical Agriculture and Food Security,
Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia
Email: akhmal.halways@gmail.com
Tel: +03-97691830
Fax: +03-89439745

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ABSTRACT

Poultry production in Malaysia is heavily dependent on imported feed ingredients. There is a need to utilize local feed ingredients such as palm kernel expeller (PKE) to sustain poultry industry through physical treatments and so that it suitable to be incorporated into the feeds. Hence this study evaluates on the effects of control (0% PKE), untreated PKE (UPKE) , extruded PKE (EPKE), less-shell PKE (LSPKE) and extruded less-shell PKE (ELSPKE) at 10%, 20% and 30% inclusion rates in finisher diets (d 21-42) showed that growth performance of broilers (Cobb 500) fed 10% PKE, 20% LSPKE and ELSPKE, were comparable to control birds. At 30% PKE inclusion, broilers performance was significantly ($P<0.05$) reduced. Birds fed PKE diets, irrespective of treatments and inclusion levels had lower LDL and total cholesterol, and similar villi height and crypt depth compared to control. At 30% PKE inclusion level, although energy metabolism was enhanced, as indicated by the up-regulation of hexokinase I and phosphofructokinase, but broilers growth performance did not improve. The feeding trial showed that broilers fed 25% or 30% LSPKE (grower feed, d 16-24), followed by 20% LSPKE (finisher feed, d 25-35) containing feed supplements 0.02% commercial enzymes and 0.30% humic acid), had comparable FI, BWG and FCR to broilers fed commercial feeds. Broilers fed 25% or 30% UPKE (grower feed, d 16-24) followed by 20% UPKE (finisher feed, d 25-35) showed significantly higher ($P<0.05$) FCR compared to birds fed commercial feeds. The cost of feeds for production of birds fed LSPKE feeds (2.27-2.29 RM/kg liveweight), was lower than those fed commercial feeds (2.36 RM/kg liveweight). The study showed that physical treatments enhanced the nutritive value of PKE and feeds containing 25-30% and 20% LSPKE as grower and finisher rations, respectively, could attain broilers growth performance comparable to broilers fed commercial feeds.

INTRODUCTION

The substitution of lignocellulosic biomass in poultry feeds had inevitable benefits especially in feed cost reduction. The main challenge faced is its high insoluble fiber content that is hard to digest by broiler with monogastric digestive system. Palm kernel expeller (PKE) is a major agricultural by-product in oil palm industries. Experiments using PKE containing diet showed repression in growth performance of broilers (Chapter 4), broilers aged 42 days in the experimental group (20% less-shell PKE) weighed 2716 g/bird with feed conversion ratio (FCR) of 1.82 and in control group (without PKE) weighed 2729 g/bird with FCR of 1.81. The result agreed with findings of [1,2]. The former study reported a retarded growth in broilers fed with 20% PKE, while the latter observed a lower average broilers weight and higher FCR in experimental group fed with 24% PKE (2308 g/bird; 1.69) as compared to control group (2371 g/bird; 1.65). When those research data were compared to Cobb broiler

management guide by [3] which described the growth performance of broilers fed with commercial diets, only FCR values reported by [2] were of equivalent to the Cobb 500 broilers standard FCR. However, the weight gain was not as good as expected. As stated in Cobb broiler management guide [3], the FCR of Cobb 500 broilers consuming commercial diet was 1.53 on day 35 and achieved 1.68 at the age of 42 days, with an average weight gain of 2191 and 2857 g/bird respectively.

The nutritional value and quality of poultry feed can be raised by incorporating bio-agent and chemical components. Feed additives such as humic acid and enzyme proteins can act as supplements to increase nutrient availability, reduce risk of diseases due to malnutrition and improve overall growth performance. A reported meta-analysis of broiler chicken pen trials with enzymes supplemented diets improved broiler weight gain at 3.73% and obtained a FCR reduction of 2.64% in 15 countries [4]. Meanwhile, humic acid supplementation in diets achieved 4% improvements in average broilers weight and 7% reduction in FCR [5]. Enhanced growth performance was also observed in study by [6] when both humic acid and enzymes were incorporated in broiler meals.

While there are many studies on usage of PKE in broilers feed, studies on enhancement of PKE meal by addition of supplements are lacking. Thus, this study aimed to improve the growth performance of broiler chickens fed on PKE meal by supplementing feed additives.

MATERIALS AND METHODS

Birds and Dietary Trial 1

In the first dietary trial, the experimental birds' groups were fed with PKE meals with feed additives during finisher period. As shown in **Table 1**, the composition of finisher diets was manipulated to make up 3 treatment groups: commercial feed, untreated PKE (UPKE) feed and less-shell PKE (LSPKE) feed. PKE containing finisher diets were added with 0.02% enzyme mix (Allzyme SSF, Alltech Inc.) and 0.3% humic acid. Commercial finisher feed was prepared as recommended by Cobb Breeder Company [3]. Meanwhile, another two treatment groups were added 20% PKE to finisher dietary feed. The calorific value and nitrogen content were standardised for all treatment groups.

Five hundred- and seventy-six-day-old chicks (Cobb 500) were randomly assigned to three treatment groups, with six replicates per treatment and thirty-two birds per replicate pen. The birds were provided with starter feed for first 15 days, grower feed for following 9 days and 3 different finisher feed during finisher period (day 25-35). Commercial starter and commercial grower feed were in crumble form while finisher feeds were in pellet form and prepared by NAFAS Feedmills Sdn Bhd.

Growth Performance

Weight gain and feed consumption were recorded on day 0 and the end of starter, grower and finisher period. The data collected was used to calculate average broiler body weight (BW), feed intake and FCR (kg of rations consumed per kg of weight gain). To increase data accuracy, the FCR was corrected for mortality.

Table 1. Ingredients composition of finisher diets (day 25-35).

	Dietary treatments		
Ingredients (%)	Commercial	UPKE	LSPKE
Soybean meal	-	10.00	10.00
Corn, grain	-	48.35	48.35
Corn gluten meal	-	5.00	5.00
UPKE	-	20.00	0.00
LSPKE	-	0.00	20.00
Feather meal, poultry	-	2.00	2.00
Full fat soybean meal	-	3.00	3.00
Crude palm oil	-	6.30	6.30
L-Lysine HCl	-	0.60	0.60
DL-Methionine	-	0.46	0.46
Threonine	-	0.16	0.16
MDCP 21	-	1.00	1.00
Limestone	-	2.24	2.24
NaCl	-	0.30	0.30
Vitamin premix[1]	-	0.05	0.05
Mineral premix[2]	-	0.10	0.10
Crude enzymes[1]	-	0.02	0.02
Humic acids	-	0.30	0.30
Total	-	100	100
Calculated composition			
Crude protein (%)	19.19	19.70	19.70
Ether extract (%)	6.80	9.80	9.80
ME (kcal/g)	3.17	3.20	3.20
Crude fibre (%)	3.00	5.13	3.71
Lysine (%)	-	1.16	1.16
Methionine (%)	-	0.84	0.84
Threonine (%)	-	0.74	0.74
Calcium (%)	0.90	1.11	1.11
Total Phosphorus (%)	0.60	0.63	0.63

Note:
Commercial feed of unknown formula
UPKE: Untreated palm kernel expeller
LSPKE: Less-shell palm kernel expeller [1]
ME: Metabolizable Energy
Vitamin premix supplied per ton of diet: Vitamin E, 75.000; vitamin K3, 20.000 g; vitamin A, 50.000 MIU; vitamin D3, vitamin B1, 10.000 g; vitamin B6, 20.000 g; vitamin B2, 30.000 g; calcium D-pantothenate, 60.000 g; vitamin B12, 0.100 g; folic acid, 5.000 g; nicotinic acid, 200.000 g; biotin, 235.000 mg.
[2]Mineral premix supplied per ton of diet: Fe, 80 g; Cu, 15 g; Zn, 80 g; Mg, 100 g; Se, 0.20 g; KCl, 4 g; MgO2, 0.60 g; NaHCO3.
[3]Crude enzymes supplied per ton of diet: pectinase, 4000 AJDU/g; protease, 700 HUT/g; phytase, 300 SPU/g; betaglucanase, 200 BGU/g; xylanase, 100 XU/g; cellulase, 40 CMCU/g; Amylase, 30 FAU/g

Birds and Dietary Trials 2

In the second dietary trial, the experimental birds' groups were fed with PKE meals with addition of supplements during grower and finisher period. As shown in **Table 2** and **Table 3**, the composition of grower and finisher diets were manipulated to make up 5 treatment groups: commercial feeds (0% PKE), UPKE containing feeds (25% in grower and 20% in finisher feed; 30% in grower and 20% in finisher feed), and LSPKE containing feeds (25% in grower and 20% in finisher feed; 30% in grower and 20% in finisher feed). PKE used had apparent metabolizable energy (AME) of 9.45 MJ/kg as reported by Sundu et al. [7].

Table 2. Ingredients composition of grower diets (day 16-24).

Ingredients (%)	Dietary Treatments				
	Group 1	Group 2	Group 3	Group 4	Group 5
Soybean meal	-	10.88	10.88	10.21	10.21
Corn, grain	-	41.03	41.03	36.48	36.48
Corn gluten meal	-	4.00	4.00	3.50	3.50
UPKE (AME = 9.45 MJ/kg)	-	25.00	0.00	30.00	0.00
LSPKE (AME = 9.45 MJ/kg)	-	0.00	25.00	0.00	30.00
Feather meal, poultry	-	3.32	3.32	3.32	3.32
Full fat soybean meal	-	4.13	4.13	4.22	4.22
Crude palm oil (CPO)	-	6.87	6.87	7.50	7.50
L-Lysine HCl	-	0.61	0.61	0.61	0.61
DL-Methionine	-	0.25	0.25	0.25	0.25
Threonine	-	0.15	0.15	0.15	0.15
MDCP 21	-	1.35	1.35	1.35	1.35
Limestone		1.50	1.50	1.50	1.50
Nacl		0.30	0.30	0.30	0.30
Vitamin premix[1]	-	0.05	0.05	0.05	0.05
Mineral premix[2]	-	0.10	0.10	0.10	0.10
Thohira premix[3]	-	0.14	0.14	0.14	0.14
Crude enzyme[4]	-	0.02	0.02	0.02	0.02
Humic acids	-	0.30	0.30	0.30	0.30
Total	-	100	100	100	100
Calculated composition					
Crude protein (%)	20.80	20.80	20.81	20.80	20.80
Ether extract (%)	10.12	10.53	10.53	11.30	11.30
ME (kcal/g)	3.17	3.17	3.17	3.17	3.17
Crude fibre (%)	3.74	5.80	4.05	6.50	4.40
Lysine (%)	1.19	1.20	1.20	1.19	1.19
Methionine (%)	0.48	0.62	0.62	0.63	0.63
Threonine (%)	0.78	0.78	0.78	0.77	0.77
Calcium (%)	0.91	0.90	0.90	0.91	0.91
Phosphorus (%)	0.76	0.74	0.74	0.76	0.76

Note:
UPKE: Untreated palm kernel expeller
LSPKE: Less-shell palm kernel expeller
Group 1, commercial grower diet (unknown formula); Group 2: 25% UPKE grower diet; Group 3: 25% LSPKE grower diet; Group 4: 30% UPKE grower diet; Group 5: 30% LSPKE grower diet.
[1]Vitamin premix supplied per ton of diet: Vitamin E, 75.000; vitamin K3, 20.000 g; vitamin A, 50.000 MIU; vitamin D3, vitamin B1, 10.000 g; vitamin B6, 20.000 g; vitamin B2, 30.000 g; calcium D-pantothenate, 60.000 g; vitamin B12, 0.100 g; folic acid, 5.000 g; nicotinic acid, 200.000 g; biotin, 235.000 mg.
[2]Mineral premix supplied per ton of diet: Fe, 80 g; Cu, 15 g; Zn, 80 g; Mg, 100 g; Se, 0.20 g; KCl, 4 g; MgO2, 0.60 g; NaHCO3. [3]Thohira premix supplied per ton of diet: propionic acid, 24%; citric acid, 10%; phosphoric acid, 4%; ammonium propionate, 5%; 1,2-propandiol, 4%; ethoxyquin, 6%; butylated hydroxytoluene, 5%.
[4]Crude enzymes supplied per ton of diet: pectinase, 4000 AJDU/g; protease, 700 HUT/g; phytase, 300 SPU/g; betaglucanase, 200 BGU/g; xylanase, 100 XU/g; cellulase, 40 CMCU/g; amylase, 30 FAU/g

Nine hundred- and sixty-day-old chicks (Cobb 500) were randomly assigned to five treatment groups, with six replicates per treatment and thirty-two birds per replicate pen. The birds were provided with starter feed for first 15 days, 5 different grower feeds during grower period (day 16-24) and 3 different finisher feeds during finisher period (day 25-35). Commercial starter and commercial grower feed were in crumble form while finisher feeds were in pellet form and prepared by NAFAS Feedmills Sdn Bhd. **Table 4** and **Table 5** summarized the feed cost for grower and finisher dietary feed respectively.

Table 3. Ingredients composition of finisher diets (day 25-35).

Ingredients (%)	Experimental groups				
	Group 1	Group 2	Group 3	Group 4	Group 5
Soybean meal	-	10.00	10.00	10.00	10.00
Corn, grain	-	48.35	48.35	48.35	48.35
Corn gluten meal	-	5.00	5.00	5.00	5.00
UPKE (AME = 9.45 MJ/kg)	-	20.00	0.00	20.00	0.00
LSPKE (AME = 9.45 MJ/kg)	-	0.00	20.00	0.00	20.00
Feather meal, poultry	-	2.00	2.00	2.00	2.00
Full fat soybean meal	-	3.00	3.00	3.00	3.00
Crude palm oil	-	6.30	6.30	6.30	6.30
L-Lysine HCl	-	0.60	0.60	0.60	0.60
DL-Methionine	-	0.46	0.46	0.46	0.46
Threonine	-	0.16	0.16	0.16	0.16
MDCP 21	-	1.00	1.00	1.00	1.00
Limestone		2.24	2.24	2.24	2.24
NaCL		0.30	0.30	0.30	0.30
Vitamin premix[1]	-	0.05	0.05	0.05	0.05
Mineral premix[2]	-	0.10	0.10	0.10	0.10
Crude enzyme[3]	-	0.02	0.02	0.02	0.02
Humic acids	-	0.30	0.30	0.30	0.30
Total	-	100	100	100	100
Calculated composition					
Crude protein (%)	19.19	19.70	19.70	19.70	19.70
Ether extract (%)	6.80	9.80	9.80	9.80	9.80
ME (kcal/g)	3.17	3.20	3.20	3.20	3.20
Crude fibre (%)	3.00	5.13	3.71	5.13	3.71
Lysine (%)	-	1.16	1.16	1.16	1.16
Methionine (%)	-	0.84	0.84	0.84	0.84
Threonine (%)	-	0.74	0.74	0.74	0.74
Calcium (%)	0.90	1.11	1.11	1.11	1.11
Phosphorus (%)	0.60	0.63	0.63	0.63	0.63

Note:
UPKE: Untreated palm kernel expeller
LSPKE: Less-shell palm kernel expeller
Group 1, commercial finisher diet (unknown formula); Group 2: 20% UPKE finisher diet; Group 3: 20% LSPKE finisher diet; Group 4: 20% UPKE finisher diet; Group 5: 20% LSPKE finisher diet.
[1]Vitamin premix supplied per ton of diet: Vitamin E, 75.000; vitamin K3, 20.000 g; vitamin A, 50.000 MIU; vitamin D3, vitamin B1, 10.000 g; vitamin B6, 20.000 g; vitamin B2, 30.000 g; calcium D-pantothenate, 60.000 g; vitamin B12, 0.100 g; folic acid, 5.000 g; nicotinic acid, 200.000 g; biotin, 235.000 mg.
[2]Mineral premix supplied per ton of diet: Fe, 80 g; Cu, 15 g; Zn, 80 g; Mg, 100 g; Se, 0.20 g; KCl, 4 g; MgO2, 0.60 g; NaHCO3.
[3]Crude enzymes supplied per ton of diet: pectinase, 4000 AJDU/g; protease, 700 HUT/g; phytase, 300 SPU/g; betaglucanase, 200 BGU/g; xylanase, 100 XU/g; cellulase, 40 CMCU/g; amylase, 30 FAU/g

Pellet Durability Index

An important criterion, pellet durability index (PDI) measures the feed pellet quality by evaluating degree of acceptance after repeated handling. PDI can be evaluated by procedures suggested by [8] and computed by dividing mass of pellets retained after tumbling over initial mass of pellet before tumbling. Samples were screened on 2.0 mm sieve to first exclude unwanted fine particles. 200g of pellet that were retained on sieve were put in tumbling device (PDI500, Halways Sdn Bhd, Serdang Selangor) for 10 min at 50 rpm [9]. Samples that successfully retained on 1.0 mm sieve after tumbling was weighed and recorded as mass of retained pellet.

Table 4. Cost calculation of grower diets (day 16-24).

Ingredients	Cost per ton (RM)					
	Price of ngredients per ton (RM)	Group 1	Group 2	Group 3	Group 4	Group 5
Soybean meal	1670.00	-	181.70	181.70	170.51	170.51
Corn, grain	895.00	-	367.22	367.22	326.50	326.50
Corn gluten meal	2855.00	-	114.20	114.20	99.93	99.93
UPKE	600.00	-	150.00	0.00	180.00	0.00
LSPKE	704.20	-	0.00	176.05	0.00	211.26
Feather meal, poultry	2200.00	-	73.04	73.04	73.04	73.04
Full fat soybean meal	2260.00	-	93.34	93.34	95.37	95.37
Crude palm oil (CPO)	3500.00	-	240.45	240.45	262.50	262.50
L-Lysine HCl	6405.00	-	39.07	39.07	39.07	39.07
DL-Methionine	16300.00	-	40.75	40.75	40.75	40.75
Threonine	7500.00	-	11.25	11.25	11.25	11.25
MDCP 21	2050.00	-	27.68	27.68	27.68	27.68
Limestone	210.00		3.15	3.15	3.15	3.15
Nacl	355.00		1.07	1.07	1.07	1.07
Vitamin premix	56000.00	-	28.00	28.00	28.00	28.00
Mineral premix	4400.00	-	4.40	4.40	4.40	4.40
Thohira premix	8785.70	-	12.30	12.30	12.30	12.30
Crude enzyme	70000.00	-	14.00	14.00	14.00	14.00
Humic acids	1505.00	-	4.52	4.52	4.52	4.52
Cost per ton (RM)		1518.40	1406.12	1432.17	1394.02	1425.28

Note:
The price according to Halways Sdn Bhd on 19th March 2017
UPKE: Untreated palm kernel expeller
LSPKE: Less-shell palm kernel expeller

Table 5. Cost calculation of finisher diets (day 25-35).

Ingredient	Cost per ton (RM)					
	Price of ingredients per ton (RM)	Group 1	Group 2	Group 3	Group 4	Group 5
Soybean meal	1670.00	-	167.00	167.00	167.00	167.00
Corn, grain	895.00	-	432.73	432.73	432.73	432.73
Corn gluten meal	2855.00	-	142.75	142.75	142.75	142.75
UPKE	600.00	-	120.00	0.00	120.00	0.00
LSPKE	704.20	-	0.00	140.84	0.00	140.84
Feather meal, poultry	2200.00	-	44.00	44.00	44.00	44.00
Full fat soybean meal	2260.00	-	67.80	67.80	67.80	67.80
Crude palm oil	3500.00	-	220.50	220.50	220.50	220.00
L-Lysine HCl	6405.00	-	38.43	38.43	38.43	38.43
DL-Methionine	16300.00	-	74.98	74.98	74.98	74.98
Threonine	7500.00	-	12.00	12.00	12.00	12.00
MDCP 21	2050.00	-	20.50	20.50	20.50	20.50
Limestone	210.00		4.70	4.70	4.70	4.70
Nacl	355.00		1.07	1.07	1.07	1.07
Vitamin premix	56000.00	-	28.00	28.00	28.00	28.00
Mineral premix	4400.00	-	4.40	4.40	4.40	4.40
Crude enzyme	70000.00	-	14.00	14.00	14.00	14.00
Humic acids	1505.00	-	4.52	4.52	4.52	4.52
Cost per ton (RM)		1518.80	1397.38	1418.22	1397.38	1418.22

Note:
The price according to Halways Sdn Bhd on 19th March 2017
UPKE: Untreated palm kernel expeller
LSPKE: Less-shell palm kernel expeller

Statistical analysis

The experimental data were further analysed for homogeneity of variances and sample means using Minitab software (version 17.1.0, 2013, Minitab Pty Ltd, Sydney Australia). Differences among variance and mean of treatment groups were tested using one-way analysis of variance (ANOVA) and Tukey test respectively, to detect any significant difference with $p<0.05$.

RESULTS AND DISCUSSION

Growth Performance

In the finisher period (day 25-35) of feeding trial 1, FI of broilers fed commercial diet (0% PKE) and those fed 20% LSPKE were not significantly different ($p>0.05$) as presented in **Table 6**. From tabulated result, UPKE diet caused a significant reduction in FI to 1616 g/bird as compared to those fed with PKE free diet (FI= 1774 g/bird) but had no significant difference in FI with those fed LSPKE diet. Meanwhile, FI of broilers in all treatment groups throughout experimental period (day 1-35) showed no significant difference. Broilers observed to have lower BW when fed with UPKE, but there's no significant different BW values among them during finisher period and throughout the experimental period. FCR in group with LSPKE diet was the lowest, but no significant difference was observed between all treatment groups during either finisher period or overall growth cycle.

The observations on broilers growth performance suggested that 20% LSPKE is more suitable to be substituted in finisher feed than UPKE as the specific treatment group had a better BW and FCR although the differences were not significant. Broilers fed with UPKE although showed weaker performance in FI, BW and FCR but the retardation effect was not significant with control group fed with PKE free diet. The possible reason is the short treatment duration as the growth promoters are only supplied during finisher period which lasts for 10 days. A more obvious distinction between LSPKE and PKE meals are expected to be observed with elongated experimental period, when beneficial effect of feed additives can be unshaded by effect of PKE on broilers productive performance.

Table 6. Feed intake weight gain and feed conversion ratio (FCR) of broilers fed commercial feed and formulated finisher feed of feeding trial 1.

Parameter	Commercial	20% UPKE	20% LSPKE	SEM
Feed intake (g/bird)				
Day 1-15	844	822	814	7
Day 16-24	932	977	961	12
Day 25-35	1774*	1616*	1695*	19
Day 1-35	3528	3389	3449	20
Body weight gain (g/bird)				
Day 1-15	643	634	628	7
Day 16-24	629	662	660	12
Day 25-35	928	844	931	17
Day 1-35	2199	2139	2219	15
FCR				
Day 1-15	1.31	1.30	1.30	0.02
Day 16-24	1.48	1.48	1.46	0.02
Day 25-35	1.94	1.94	1.82	0.07
Day 1-35	1.61	1.59	1.55	0.04

Note:
Means ± SEM with different superscripts in a row differ significantly ($P < 0.05$). Finisher feed (d 25-35) containing either 20% untreated PKE (UPKE) or 20% less-shell PKE (LSPKE).

The growth performance of experimental broilers in feeding trial 1 was not far behind with Cobb 500 broilers standard growth performance published in management guide [3]. This study reported BW between 2139 to 2219 g/bird and FCR in the range of 1.55 to 1.61, were comparable with the management guide where BW and FCR on day 35 were 2191 g/bird and 1.53 respectively.

The combination of vitamin premix, mineral premix, enzymes and humic acid in supplement added in feed according to feed formulation used in industrial practices was able to improve feed quality to meet expectation on broilers growth performance (Nor'Asyikin Mochamat, personal communication, Jan 10, 2018). From the result, it can be concluded that by adding enzymes and humic acid, both UPKE and LSPKE can be substituted in finisher feed at 20%. When compared with results shown in Chapter 5, addition of feed supplements had brought enhancement on broilers growth performance.

The role of dietary exogenous enzymes in promoting growth of broiler chickens had been widely studied [10,4,11]. Indigestible lignocellulosic composition in palm kernel cake (PKC) can be hydrolysed by enzyme additives containing pectinase, protease, phytase, beta-glucanase, xylanase, cellulose and amylase. Therefore, enzyme supplements was common in feed milling as they are able improve digestible energy and protein, resulting in a better intestinal morphology, intestinal secretory and absorptive abilities, enhance immune resilience and thus increase the FCR [11] Mixed xylanase, amylase and protease enzymes supplement in maize based broilers feed brought 3% improvement in AME, according to [10]. It was reported an increase by 3.73% in broilers BW and reduction in FCR by 2.64% when fed with diets fortified with Allzymes in independent commercial broilers feeding trials [4]. However, addition of exogenous enzymes in broilers diet with 16% and 24% palm kernel meal do not affect the FCR, the improving effects were only seen in broilers fed with 0% and 8% palm kernel meal [12]. This may be due to different enzymes being applied and humic acid deficiency in the broiler diet.

The ban of antibiotics in animal feed [13] had contribute to numerous efforts in replacing antibiotics with other growth promoters in broiler diet including humic acid-based mixture [14]. Humic acid, by-product resulted from decomposition of plant and animal matter (humic substances) possess antimicrobial, antifungal and many other beneficial effect [15]. When incorporated in feed, it was found to stabilize gut microbiota and increase bioavailability of nutrients in feed, therefore helping in growth performance of birds [16]. A dosage of humic acid at 2mL/L drinking water helped enhancement of growth, nutrient absorption and FCR in broilers as reported by [17]. The beneficial effect of enzymes and humic acid as growth promoters in finisher feeds of broilers could be seen in this experiment as the BW and FCR values of PKE treated broilers meet the standard in Cobbs 500 management guide.

To enlarge the effect of PKE and feed additives on growth performance of broilers, feeding trial 2 was carried out with elongated feeding period from 10 days (finisher period) to 20 days (grower and finisher period). FI, BW and FCR of broilers in feeding trial 2 were tabulated in **Table 7**. From the table, no significant difference between FI of all the 5 treatment groups being spotted throughout the experimental period. For BW of broilers, there's were no obvious distinction during starter period as same starter feed was supplied. Broilers fed with grower feeds containing either UPKE or LSPKE showed similar BW during grower period. When compared with commercial dietary group (Group 1), similar BW of broilers from Group 2 and Group 5 were noticed, while broilers from Group 3 and Group 4 showed significantly lower BW during grower period. Broilers fed with finisher feeds containing either 20% UPKE or 20% LSPKE showed similar BW with treatment group fed with PKE free feed, except for Group 4. Group 4 broilers, which had been fed with 30% and 20% UPKE during grower and finisher periods respectively, were observed to have significantly lower BW than other treatment groups during finisher period. Throughout both treatment period (20 days) and experimental period, Group 4 with UPKE feed had reported a significantly lower BW than Group 5 with LSPKE feeds at same dosage.

Table 7. Feed intake, weight gain and feed conversion ratio (FCR) of broilers fed commercial feed and treatments diets.

Parameter	Group 1	Group 2	Group 3	Group 4	Group 5	SEM
Feed intake (g/bird)						
Day 1-15	699	706	729	717	726	4
Day 16-24	1103	1171	1101	1170	1149	9
Day 25-35	1730	1715	1689	1704	1759	10
Day 16-35	2833	2885	2791	2873	2908	16
Day 1-35	3532	3590	3520	3572	3634	16
Body weight gain (g/bird)						
Day 1-15	495	496	507	494	511	3
Day 16-24	830^{a}	794^{ab}	760^{b}	778^{b}	797^{ab}	6
Day 25-35	955^{ab}	934^{ab}	980^{a}	897^{b}	998^{a}	10
Day 16-35	1785^{a}	1729^{ab}	1740^{ab}	1675^{b}	1794^{a}	12
Day 1-35	2280^{a}	2224^{ab}	2247^{ab}	2169^{b}	2306^{a}	13
FCR						
Day 1-15	1.41	1.42	1.44	1.42	1.42	0.01
Day 16-24	1.33^{b}	1.47^{a}	1.45^{a}	1.50^{a}	1.44^{a}	0.01
Day 25-35	1.82^{ab}	1.84^{ab}	1.73^{b}	1.90a	1.76^{b}	0.02
Day 16-35	1.59^{c}	1.67^{ab}	1.60^{bc}	1.72^{a}	1.62^{bc}	0.01
Day 1-35	1.55^{c}	1.61^{ab}	1.57^{bc}	1.65^{a}	1.58^{bc}	0.01

Note:
Means with different superscripts in a row differ significantly ($P < 0.05$).
Group 1: commercial starter, grower and finisher diet; Group 2: commercial starter, 25% UPKE grower and 20% UPKE finisher diet; Group 3: commercial starter, 25% LSPKE grower and 20% LSPKE finisher diet; Group 4: commercial starter, 30% UPKE grower and 20% UPKE finisher diet; Group 5: commercial starter, 30% LSPKE grower and 20% LSPKE finisher diet.

For FCR of broilers, there's were no obvious difference during starter period as same starter feed was fed. During grower period, Group 4 (fed 30% UPKE) had the highest FCR at 1.50 while Group 2 (fed 25% UPKE) had the second highest FCR at 1.47. Broilers fed with grower feeds containing either UPKE or LSPKE showed similar ($p>0.05$) FCR but their FCR were significantly higher ($p<0.05$) than control group with commercial diets. Despite no obvious differences between treatment groups with different PKE diets, broilers fed with LSPKE had lower FCR than those fed with UPKE during grower period. Meanwhile during finisher period, Group 4 (fed 20% UPKE) had the significant higher FCR at 1.90 than Group 3 and Group 5 (fed LSPKE) with range of FCR of 1.73 and 1.76. Throughout both treatment period (20 days) and whole experimental period (35 days), FCR of broiler groups with UPKE diets are significantly higher than control group with PKE free diet, while FCR of broiler groups with LSPKE diets were similar with control group with PKE free diet.

The observations in feeding trial 2 suggested that by adding enzymes and humic acid, the substitution 25% to 30% of LSPKE in grower feed and 20% LSPKE in finisher feed for broilers had no detrimental effect on growth performance of broilers, as compared to control group with PKE free diet. As to prevent side effect on anatomy and physiology of digestive tract of broilers due to consumption of high-fiber diets in the long run [18], the PKE content of fed given during finisher period was reduced to 20%. In the dietary trial 2, UPKE diets provided contained the highest percentage of crude fiber at 5.8 to 6.5%, followed by LSPKE diets with 4.05 to 4.4% crude fiber content and lowest crude fiber content in commercial diets at a value of 3% and lower as presented in **Table 3**. It was found that during grower period, UPKE and LSPKE feed at inclusion rate of either 25% or 30% showed no significant different effect on BW of broilers. Meanwhile during finisher period, broilers in treatment groups fed with UPKE or LSPKE feeds showed comparable BW with treatment group undergone a commercial diet. A significant retardation on weight gain during finisher period was spotted in

Group 4 which fed with 30% UPKE grower feed in comparison with group fed with 30% LSPKE grower feed. It was clearly shown in **Table 2** that UPKE diet rich in fiber content (6.5%) during grower period resulted in affected growth performance in broilers (Group 4), while UPKE diet with lower crude fiber content (5.8%) during grower period did not affect growth performance in broilers (Group 2). Fibers are reported to possess anti-nutritive properties by entrapment of nutrients in its fibrous cell walls and would affect enzyme accessibility and nutrient absorption [19,20]. The encapsulation of nutrients by aleurone was observed in study by [19] in dietary treatment on pigs fed with rye aleurone high in non-starch polysaccharides (NSP) content which had resulted in affected digestibility of starch, protein and fat.

As compared to first dietary trial with 10 days treatment period where application of LSPKE feed in broilers resulted in similar FCR with control group with commercial feed, and showed a slightly lower FCR ($p>0.05$) than group fed with UPKE feed throughout the experimental period, second dietary trial with 20 days treatment period resulted in significantly lower FCR ($p<0.05$) in broiler groups with LSPKE diets than group fed with UPKE feed, and yet had comparable FCR with control group throughout the experimental period. The adverse effect of PKE and influence of feed supplement (enzymes and humic acid) on growth performance of broilers, was more obvious with elongated feeding period from 10 days (finisher period) to 20 days (grower and finisher period) in dietary trial 2. Moreover, the growth performance of experimental broilers in feeding trial 2 was not far behind with Cobb 500 broilers standard growth performance published in management guide [3]. This study reported BW of 2247-2306 g/bird and FCR in the range of 1.57 to 1.58 on day 35 in broilers followed LSPKE diet on day 35, which were comparable with the management guide where BW and FCR on day 35 were 2191 g/bird and 1.53 respectively.

Cost of PKE Feeds

A comparison of feed cost for commercial feed and PKE containing feed was done and summarized in **Table 8**. The calculation of feed cost was referred to real time market price (during experiment period) of the raw ingredients involved in formulate. 1 type of starter diet, 5 types of grower diets and 3 types of finisher diets were used in dietary trial 2. From **Table 8**, the grower feed cost (RM/kg) from lowest to highest was Group 4 (1.39) < Group 2 (1.41) < Group 3 (1.43) < Group 5 (1.52) < Group 1; while the finisher feed cost was lowest in UPKE feed, followed by LSPKE feed and highest in commercial feed. Higher cost in PKE with less shell fraction than raw PKE was due to pre-processing including static cling and electrostatic separation.

Table 8. Feed formulation cost analysis.

Feed cost per kg	Group 1	Group 2	Group 3	Group 4	Group 5
Starter (RM)	1.56	1.56	1.56	1.56	1.56
Grower (RM)	1.52	1.41	1.43	1.39	1.43
Finisher (RM)	1.51	1.40	1.42	1.40	1.42

Note:
Group 1: commercial starter, grower and finisher diet; Group 2: commercial starter, 25% UPKE grower and 20% UPKE finisher diet; Group 3: commercial starter, 25% LSPKE grower and 20% LSPKE finisher diet; Group 4: commercial starter, 30% UPKE grower and 20% UPKE finisher diet; Group 5: commercial starter, 30% LSPKE grower and 20% LSPKE finisher diet.

As presented in **Table 9**, PKE based grower feeds which is cheaper than PKE free commercial grower feed did not contribute to any significant reduction in production cost per live weight gain in kg during grower period. Meanwhile, only finisher feed substituted with LSPKE obtained a significantly lower production cost (feed/kg live weight) than control group fed with commercial finisher feed, groups with UPKE finisher feed had similar production cost with the control group. In overall, dietary trial 2 recorded significantly lower production cost in grower and finisher feeds for Group 5 at 2.31 RM/kg live weight but a significant lower overall production cost for Group 3 when compared to control group fed with commercial feed.

Table 9. Production cost analysis (cost of feed/kg chicken).

Cost of feed per kg chicken (RM)	Group 1	Group 2	Group 3	Group 4	Group 5	SEM
Starter	2.20	2.22	2.24	2.27	2.22	0.02
Grower	2.02	2.08	2.07	2.09	2.06	0.01
Finisher	2.74^{a}	2.58^{abc}	2.45^{c}	2.66^{ab}	2.50^{bc}	0.03
Grower and finisher	3.02^{a}	2.98^{ab}	2.94^{b}	3.06^{a}	2.31^{c}	0.06
Overall cost	2.36^{a}	2.32^{ab}	2.27^{b}	2.37^{a}	2.29^{ab}	0.01
Overall cost saving*	0.00	0.04	0.09	-0.01	0.07	-

Note:
Means with different superscripts in a row differ significantly ($P < 0.05$).
Group 1: commercial starter, grower and finisher diet; Group 2: commercial starter, 25% UPKE grower and 20% UPKE finisher diet; Group 3: commercial starter, 25% LSPKE grower and 20% LSPKE finisher diet; Group 4: commercial starter, 30% UPKE grower and 20% UPKE finisher diet; Group 5: commercial starter, 30% LSPKE grower and 20% LSPKE finisher diet.
*Compared to commercial feed

Except for Group 4 in dietary trial 2, the difference in production cost among other treatment groups was similar. While in term of the difference in production cost as compared to control commercial diet group, total cost saving or profit would be highest in Group 3, second highest in Group 5 at which both of them followed LSPKE diets. If calculated in larger commercial broilers farm, a more substantial projected profit margin was expected. For instance, if the LSPKE dietary treatment for Group 3 was used in a broilers farm that currently fed with commercial feed, the farm production capacity and average body weight given as 100,000 birds and 2.0 kg/bird respectively, the saving in production cost which is 4% would be RM 18,000 per growth cycle (35 days).

Pellet Quality

PDI for all dietary treatments which indicating the ability of pellets to withstand repeated handling procedures without unacceptable degradation [21], was tabulated in **Table 10**. PDI of commercial grower and finisher feeds was significantly higher than PKE containing feeds. The results agreed with [12] whom reported that the higher palm kernel meal (PKM) content in feed pellet, the lower the PDI value. In his study, the dietary feeds with increasing 0%, 8%, 16% and 24% PKM had descending PDI values of 85.3, 56.2, 34.4 and 15.4, respectively.

Table 10. Pellet durability index of the grower and finisher pellets

Feed sample	Pellet Durability Index (%)	
	Grower	Finisher
Commercial feed	66.67 ± 3.51^{a}	71.00 ± 4.16^{a}
25% UPKE	53.33 ± 4.04^{b}	-
25% LSPKE	52.67 ± 3.79^{b}	-
30% UPKE	53.00 ± 5.57^{b}	-
30% LSPKE	46.67 ± 6.08^{b}	-
20% UPKE	-	55.00 ± 7.00^{b}
20% LSPKE	-	54.00 ± 5.51^{b}

Note:
Means ± standard deviation (n=3) with different letters within a column are significantly different (P<0.05).
UPKE: Untreated palm kernel expeller
LSPKE: Less-shell palm kernel expeller

Previous work has found that the effect of PKE inclusion rate on PDI was negligible when the pellets had 5.6% of oil content or lower [22]. This may be the reason why the pellet endurance capacity decreases when PKE was substituted in this study, the pellet containing PKE had oil content of 6.3 to 7.5%. Based on personal communication with Nor'Asyikin Mochamat (Jan 10, 2018), the oil content in commercial feed was approximately 3%. The effect of fat as pellet binders on physical

pellet quality was described by [23,24]. The former study reported on the role of fat as pellet coating which could resulted in resisting penetration of steam into feed components and affecting the binding mechanisms or shading the adhesive forces. Meanwhile, fat could also act as lubricant on pellet which would reduce frictional heating in milling machine and thus lowering the pellet physical quality [24]. Pellet with lower endurance ability will crumble more easily during silo transferring through screw conveyor for feeding in feed plants. To avoid such occurrence, developing PKE feed pellet with better PDI by adding suitable feed binder in feed processing was important. Higher PDI would ensure a lower rate of pellet deterioration and mass lost during pelleting [25].

CONCLUSION

The experiments had shown that substitution of LSPKE in both grower and finisher feed did not affect the growth performance of broilers as compared to those fed with commercial feeds. For application in commercial broilers farm, it is recommended that LSPKE being included in grower and finisher feed at 25%-30% and 20% respectively.

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ABBREVIATIONS

PKE Palm Kernel Expeller
UPKE Untreated Palm Kernel Expeller
EPKE Extruded Palm Kernel Expeller
LSPKE Less-Shell Palm Kernel Expeller
LDL Low-Density Lipoprotein
FI Feed Intake
BWG Body Weight Gain
FCR Feed Conversion Ratio
AME Apparent Metabolizable Energy
ME Metabolizable Energy
PDI Pellet Durability Index

REFERENCES

1. Mardhati, M., Wong, H. K., & Noraini S. Growth performance and carcass analysis of broilers fed with enhanced quality palm kernel meal. J Trop Agric Food Sci. 2011;39(9):157–66.
2. Farahiyah IJ, Wong HK, Mardhati M. Effect of mannanase-supplemented PKE-based diets on the growth performance, feed efficiency and dressing percentage of broilers. J Trop Agric Fd Sc. 2014;42(2):125–33.
3. Vantress. Cobb Broiler Management Guide. Cobb-vantress Inc. 2012;(Arkansas).
4. Hooge, D. M., Pierce, J. L., McBride, K. W., & Rigolin PJ. Meta-analysis of broiler chicken trials using diets with or without Allzyme® SSF Enzyme Complex®. Int J Poult Sci. 2010;9(9):819–23.
5. Kocabağli N, Alp M, Acar N, Kahraman R. The effects of dietary humate supplementation on broiler growth and carcass yield. Poult Sci. 2002;81(2):227–30.
6. Disetlhe ARP, Marume U, Mlambo V. Humic acid and enzymes inclusion in canola-based diets generate different responses in growth performance, protein utilization dynamics, and hemato-biochemical parameters in broiler chickens. Poult Sci. 2018;97(8):2745–53.
7. Sundu B, Kumar A, Dingle J. Palm kernel meal in broiler diets: effect on chicken performance and health. Worlds Poult Sci J. 2006;62(2):316–25.
8. Pfost, H. B. Testing the durability of pelleted feed. Feedstuffs. 1963; **23**: 66-68.
9. Thomas, M. A. F. B., & Van der Poel AFB. Physical quality of pelleted feed 1. Criteria for pellet quality. 1996. 257.
10. Cowieson AJ, Ravindran V. Effect of exogenous enzymes in maize-based diets varying in nutrient density for young broilers: Growth performance and digestibility of energy, minerals and amino acids. Br Poult Sci. 2008;49(1):37–44.
11. Cowieson AJ, Lu H, Ajuwon KM, Knap I, Adeola O. Interactive effects of dietary protein source and exogenous protease on growth performance, immune competence and jejunal health of broiler chickens. Anim Prod Sci. 2017;57(2):252–61.
12. Abdollahi MR, Ravindran V, Amerah AM. Influence of Parm Kernel Meal Inclusion and exogenous enzyme supplementation on growth performance, nutrient digestibility and energy utilization in young broilers. Asian-Australian J Anim Sci. 2016;29(4):539.
13. Engberg RM, Hedemann MS, Leser TD, Jensen BB. Effect of zinc bacitracin and salinomycin on intestinal microflora and performance of broilers. Poult Sci. 2000;79(9):1311–9.
14. Ceylan N, Çiftçi I, Ilhan Z. Effects of some alternative feed additives for antibiotic growth promoters on performance and gut microflora of broilers. Turkish J Vet Anim Sci. 2003;27(3):727–33.
15. De Melo BAG, Motta FL, Santana MHA. Humic acids: Structural properties and multiple functionalities for novel technological developments. Mater Sci Eng C. 2016;62:967–74.
16. Nagaraju, R., Reddy, B. S., Gloridoss, R., Suresh, B. N., & Ramesh C. Effect of dietary supplementation of humic acids on performance of broilers. Indian J Anim Sci. 2014;84(4):447–52.
17. Lala, A. O., Oso, A. O., Okwelum, N., Ajao, A. M., & Adegbenjo A. Response of Broiler Chickens To Varying Dosage of Humic Acid in Drinking Water. 2017;29(1):288–94.
18. Wenk C. The role of dietary fibre in the digestive physiology of the pig. Anim Feed Sci Technol. 2001;90(1–2):21–33.
19. Le Gall M, Serena A, Jørgensen H, Theil PK, Bach Knudsen KE. 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. Br J Nutr. 2009;102(11):1590–600.
20. Knudsen KEB, Jensen BB, Hansen I. 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. Br J Nutr. 1993;70(2):537–56.
21. Zaini IN, Novianti S, Nurdiawati A, Irhamna AR, Aziz M, Yoshikawa K. Investigation of the physical characteristics of washed hydrochar pellets made from empty fruit bunch. Fuel Process Technol. 2017;160:109–20.
22. Briggs JL, Maier DE, Watkins BA, Behnke KC. Effect of ingredients and processing parameters on pellet quality. Poult Sci. 1999;78(10):1464–71.
23. Löwe R. Judging pellet stability as part of pellet quality. Feed Technol. 2005;9(2):15–9.
24. Abdollahi MR, Zaefarian F, Ravindran V, Selle PH. The interactive influence of dietary nutrient density and feed form on the performance of broiler chickens. Anim Feed Sci Technol. 2018;239:33–43.
25. Behnke KC. Factors Influencing Pellet Quality. Feed Technol. 2001;5(4):19–22.