WALAILAK JOURNAL

http://wjst.wu.ac.th

Article

Diets Containing Fermented Palm Kernel Meal with *Aspergillus wentii* TISTR 3075 on Growth Performance and Nutrient Digestibility of Broiler Chickens

Niwat MUANGKEOW* **and Charurat CHINAJARIYAWONG**

Division of Animal Science, School of Agricultural Technology, Walailak University, Nakhon Si Thammarat 80161, Thailand

(*Corresponding author's e-mail: mniwat@wu.ac.th)

Received: 13 July 2012, Revised: 19 October 2012, Accepted: 21 February 2013

Abstract

The objective of the current study was to investigate the effect of palm kernel meal (PKM) and *Aspergillus wentii* TISTR 3075 fermented PKM at various levels on growth performance and nutrient digestibility of broiler chickens. Four hundred and thirty-two day old Ross-308 broiler chicks were used in a 2 × 4 factorial in completely randomized design with one control. Two kinds of PKM (unfermented and *A. wentii* fermented PKM) in broiler rations were used, each at 10, 20, 30 and 40 %. Increasing level of PKM or *A. wentii* fermented PKM higher than 20 % significantly decreased feed intake and average weight gain also decreased, while feed efficiency declined. Feed intake of growing broilers during 0 to 21 d of age fed with PKM decreased linearly followed by a quadratic response during the finishing period (22 to 42 d of age) while those broilers fed with *A. wentii* fermented PKM exhibited a quadratic response throughout the 42 d feeding trial. Data show that feed intake and average weight gain response when fed with PKM decreased linearly while when fed with *A. wentii* fermented PKM it was quadratic and then slowly decreased. The poor performance of the birds fed PKM or *A. wentii* fermented PKM at high levels might be due to the higher in crude fiber content and the lower nitrogen retention. In the growing period PKM or *A. wentii* fermented PKM no more than 20 % of the broiler ration should be used while in the finishing period PKM up to 30 % is effective.

Keywords: Fermented palm kernel meal, growth performance, nutrient digestibility, broiler chicken

Introduction

Palm kernel meal (PKM), is a by-product from the African palm (*Elaeis guinensis*) oil industry that is extensively cultivated in tropical countries. Palm kernel meal is a major source of non-starch polysaccharides (NSPs). NSPs are not hydrolyzed by mammalian enzymes. However they can be fermented by the gastrointestinal tract micro flora. NSPs can impact digestion and utilization of nutrients, such as amino acids, and minerals. With proper dietary modification diets containing ingredients high in NSPs and oligosaccharides could be efficiently utilized for both growing pigs and gestating sows [1]. The total carbohydrate in palm kernel meal, excluding lignin, is about 50 %, of which only 2.4 % is of low molecular weight and 1.1 % is starch while the rest (42 %) is in the form of NSPs [2]. Major polysaccharides in palm kernel meal are linear mannans with very low galactose substitution (78 % of total NSPs), followed by cellulose (12 %) and small amounts of (4-o-methyl)-glucuronoxylans and arabinoxylans (3 % each), which have been found to be water-insoluble [3]. In contrast, Bach Knudson [2] report that 81 % of palm kernel meal carbohydrates is in the form of NSPs. Of the total NSPs present in palm kernel meal, the main form is an insoluble non-cellulose polysaccharide, accounting for 33.6 % of the dry matter. The main sugars in the soluble non-cellulose polysaccharides were mannose and galactose while the sugars in the insoluble non-cellulose polysaccharide are also mannose and glucose. The high amount of lignin (13.6 %) in PKM may possibly be due to contamination by the nut shell.

Fermentation is a unique process with great potential for recycling some agro-industrial by-products into useful animal feeds in developing countries. Our previous study [4] found that the crude protein content was enhanced by solid state fermentation with *Aspergillus wentii* TISTR 3075 from 16.99 % to 21.36 %, sulfur containing amino acids (cysteine and methionine) and lysine were limiting amino acids in palm kernel meal (solvent extraction; PKM) and fermented palm kernel meal (FPKM) with *Aspergillus wentii* TISTR 3075. The apparent metabolizable energy (AME; DM basis) of PKM and FPKM are 2,201.83 and 2,080.26 kcal/kg, respectively. *A. wentii* may use up nitrogen-free extract (NFE) in PKM as an energy source during fermenting process, resulting in low metabolizable energy of FPKM when compared to PKM. Red tilapia raised on *Trichoderma longibrachiatum* fermented palm kernel cake (TL-PKC) from 0 to 40 % in each ration, had decreased body lipids as the TL-PKC level increased while carcass moisture increased. At 30 and 40 % both had the lowest lipid content, which was much lower than the control [5].

The objective of this study is to assess the effect of PKM and *A. wentii* fermented PKM at various levels on growth performance and nutrient digestibility of broiler chickens.

Materials and methods

Birds and housing

The experiment was conducted in floor pens with wood shavings, with a dimension of 120 × 100 cm^2 (density of 1,000 cm^2 per bird), in an environmentally controlled house. Four hundred and thirty two one-day-old straight run Ross-308 broiler chickens were randomly divided into 36 experimental units with 12 chickens in each. A 2 × 4 factorial in completely randomized design with one control was used. The first factor was the kind of PKM unfermented or A. *wentii* fermented PKM; the second factor was the level of inclusion: 10, 20, 30 and 40 % in the rations. The birds were kept under standard management conditions, and feed and water were provided *ad libitum* throughout the experimental period.

Experimental diets

Two-phase feeding (starter and finisher) was used, **Tables 1** and **2**, respectively. All nutrient contents met National Research Council (NRC) recommendations [6]. The chemical composition and nutritive value of PKM and fermented PKM by solid state fermentation with *A. wentii* were investigated by Muangkeow and Chinajariyawong [4].

Determination of nutrient digestibility

The experiment was conducted in cages with dimensions of 40 × 45 × 38 cm^3 each, supplied with nipples and feeders. A total of 27 three week old Ross-308 male chicks were used to conduct nutrient digestibility. All birds were fed starter diets in mash form (nutrient compositions identical to starter experimental diets in **Table 1**) and contained 1.0 % Celite to increase the content of acid insoluble ash [7]. The excreta were collected over a period of 48 h in individual trays attached to the bottom of the cages.

The nitrogen retention and apparent metabolizable energy (AME) were calculated using the following formulae [8]:

$$N_{\text{Retained}} = N_{Diet} - \left[\frac{N_{Excreata} \ x \ AIA_{Diet}}{AIA_{Excreta}} \right]$$

$$AME = GE_{Diet} - \left[\frac{GE_{Excreta} \ x \ AIA_{Diet}}{AIA_{Excreta}} \right]$$

Table 1 Composition of experimental diets (0 to 21 d).

Item, %	Control	Palm kernel meal				*A. wentii* fermented PKM			
		10	20	30	40	10	20	30	40
Ingredients									
Yellow corn	61.18	51.07	41.00	30.73	20.72	51.92	42.66	33.27	24.02
Palm kernel meal	0.00	10.00	20.00	30.00	40.00				
A. wentii fermented PKM	0.00					10.00	20.00	30.00	40.00
Soybean oil meal 45 % CP	25.15	23.35	21.41	19.75	17.78	22.38	19.60	16.90	14.15
Fish meal 62 % CP	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Palm olein oil	1.60	3.57	5.50	7.45	9.40	3.60	5.60	7.65	9.70
Oyster shell	1.00	0.97	0.95	0.92	0.92	0.98	0.96	0.93	0.92
Monocalcium phosphate 21 % P	0.20	0.17	0.16	0.13	0.13	0.18	0.17	0.14	0.10
Common salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
DL-Methionine	0.20	0.16	0.16	0.15	0.14	0.18	0.17	0.15	0.15
L-Lysine	0.00	0.07	0.12	0.17	0.21	0.06	0.14	0.19	0.25
Coccidiostat (Salinomycin Na)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin-mineral premix[1/]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated composition									
Crude protein	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
AME (kcal/kg)	3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080
Crude fiber	2.40	3.80	5.21	6.62	8.02	3.99	5.57	7.16	8.75
Calcium	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Available phosphorus	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Lysine	1.27	1.28	1.28	1.28	1.28	1.27	1.28	1.28	1.28
Methionine	0.57	0.57	0.58	0.57	0.57	0.59	0.58	0.57	0.57
Methionine + Cystine	1.01	0.99	0.99	0.96	0.95	1.01	0.99	0.96	0.95
Threonine	0.89	0.88	0.87	0.86	0.84	0.88	0.87	0.85	0.85
Tryptophan	0.24	0.24	0.23	0.23	0.22	0.22	0.20	0.21	0.20
Arginine	1.38	1.48	1.57	1.68	1.77	1.43	1.48	1.54	1.59

[1/] Supplied per kilogram of diets: vitamin A, 19,200 IU; vitamin D_3, 3,840 IU; vitamin E, 8 IU; vitamin K_3, 3.2 mg; thiamin, 2.4 mg; riboflavin, 6.4 mg; vitamin B_{12}, 0.0024 mg; nicotinic acid, 2.4 mg; folic acid, 0.8 mg; biotin, 0.16 mg; pantothenic acid, 16 mg; manganese, 96 mg; zinc, 160 mg; iron, 128 mg; copper, 9.6 mg; selenium, 0.24 mg.

Table 2 Composition of experimental diets (22 to 42 d).

Item, %	Control	Palm kernel meal				*A. wentii* fermented PKM			
		10	20	30	40	10	20	30	40
Ingredients									
Yellow corn	50.64	55.36	45.34	35.28	25.25	56.26	47.05	37.54	28.34
Defatted rice bran	12.00								
Palm kernel meal	0.00	10.00	20.00	30.00	40.00				
A. wentii fermented PKM	0.00					10.00	20.00	30.00	40.00
Soybean oil meal 45 % CP	22.03	20.91	19.06	17.20	15.33	19.99	17.24	14.53	11.79
Fish meal 62 % CP	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Palm olein oil	6.55	4.90	6.78	8.70	10.60	4.90	6.85	9.05	11.00
Oyster shell	1.27	1.24	1.20	1.19	1.16	1.24	1.22	1.20	1.19
Monocalcium phosphate 21 % P	0.24	0.25	0.24	0.20	0.18	0.26	0.24	0.22	0.18
Common salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
DL-Methionine	0.12	0.12	0.11	0.11	0.10	0.12	0.11	0.11	0.10
L-Lysine	0.22	0.27	0.32	0.37	0.43	0.28	0.34	0.40	0.45
Coccidiostat (Salinomycin Na)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin-mineral premix[1/]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated composition									
Crude protein	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
AME (kcal/kg)	3,170	3,170	3,170	3,170	3,170	3,170	3,170	3,170	3,170
Crude fiber	3.46	3.78	5.18	6.59	8.00	3.96	5.55	7.13	8.73
Calcium	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Available phosphorus	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Lysine	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Methionine	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Methionine + Cystine	0.84	0.83	0.81	0.80	0.79	0.82	0.80	0.79	0.77
Threonine	0.76	0.74	0.73	0.72	0.70	0.74	0.73	0.72	0.71
Tryptophan	0.22	0.20	0.20	0.19	0.19	0.20	0.19	0.18	0.17
Arginine	1.22	1.26	1.36	1.46	1.55	1.22	1.27	1.32	1.38

[1/] Supplied per kilogram of diets: vitamin A, 19,200 IU; vitamin D_3, 3,840 IU; vitamin E, 8 IU; vitamin K_3, 3.2 mg; thiamin, 2.4 mg; riboflavin, 6.4 mg; vitamin B_{12}, 0.0024 mg; nicotinic acid, 2.4 mg; folic acid, 0.8 mg; biotin, 0.16 mg; pantothenic acid, 16 mg; manganese, 96 mg; zinc, 160 mg; iron, 128 mg; copper, 9.6 mg; selenium, 0.24 mg.

Chemical analysis

A subset of diet and feces samples were analyzed in triplicate for acid insoluble ash (AIA) as reported by Scott and Boldji [7]. The ground samples and feces samples were then analyzed for dry matter (DM) by oven-drying and nitrogen (N) by Kjeldahl procedures [9]. Diet and excreta samples were assayed for gross energy (GE) in an Isoperibol bomb calorimeter (Leco AC 500) by ASTM procedures [10].

Data collection

Chicken body weight (BW) and feed consumption were determined at 7, 14, 28 and 42 d old to calculate weight gain and feed conversion. BW of dead birds was used to adjust feed consumption and feed conversion.

Statistical analysis

Performance data were analyzed, using an analysis of variance. Where significant differences among treatments were obtained, comparisons among means were performed by Tukey's honestly. Orthogonal contrasts were used when comparison between control and kinds of PKM and orthogonal polynomial contrasts were used to test the linear or quadratic nature of the response to incremental concentrations in PKM or *A. wentii* fermented PKM [11-12].

Results and discussion

Performance of broilers

Feed intake during the first 21 days of broilers fed PKM or *A. wentii* fermented PKM was highly significant (P = 0.0001) and lower than those the fed control diet. Birds fed on a diet containing PKM consumed significantly greater feed (P = 0.0001) than those fed a diet containing *A. wentii* fermented PKM (**Table 3**). Increasing levels of PKM or *A. wentii* fermented PKM to higher than 20 % result in a highly significant decrease in feed intake (P < 0.01). An interaction between the kind and level of PKM was detected (P = 0.0093) for feed intake (**Tables 3** and **4**). The average weight gain (0 to 21 d old) of broilers fed the treatment diet was not significant (P > 0.05) when compared with those fed the control diet. The average weight gain of birds fed a diet containing PKM was not significant (P > 0.05) when compared with those birds fed FPKM diets. Broilers fed a diet with PKM or *A. wentii* fermented PKM up to 40 % was highly significant (P < 0.01) and lower than broilers fed with other levels. No significant interaction (P = 0.1062) between the kind and level of PKM on average weight gain was observed during the growing period from 0 to 21 d. Feed efficiency was also not affected by dietary treatments (**Tables 3** and **4**).

Response of feed intake, average weight gain and feed conversion rate of broiler fed with PKM during the first 21 days were linearly affected (P = 0.0002 , P = 0.0001 and P = 0.0051, respectively), while broilers fed with *A. wentii* fermented PKM were quadratically affected (P = 0.0001) for feed intake (**Figure 1b**) and average weight gain (P = 0.0149) (**Table 5**).

Table 3 Effect of main effects (kinds and levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) inclusion) on the performance of growing broilers (0 to 21 d old).

Dietary treatment	**Feed intake (kg/bird)**	**Average weight gain (kg/bird)**	**Feed conversion ratio**
Control	1.385 ± 0.014	0.875.00 ± 0.053	1.59± 0.10
Probability of statistical analysis			
Control vs others	0.0001**	0.091ns	0.6033ns
Main effects:			
Kinds of PKM			
PKM	1.341 ± 0.044a	0.850 ± 0.060	1.58 ± 0.08
FPKM	1.284 ± 0.067b	0.826 ± 0.047	1.56 ± 0.06
Probability of statistical analysis	0.0001**	0.0833ns	0.2396ns
Levels of inclusion (%)			
10	1.339 ± 0.042b	0.863 ± 0.054a	1.55 ± 0.07
20	1.375 ± 0.017a	0.870 ± 0.039a	1.58 ± 0.06
30	1.291± 0.035c	0.841 ± 0.029a	1.53 ± 0.05
40	1.246 ± 0.056d	0.778 ± 0.042b	1.60 ± 0.09
Probability of statistical analysis	0.0001**	0.0002**	0.1088ns
Interaction (Kinds of PKM × Levels of inclusion)			
Probability of statistical analysis	0.0093**	0.1062ns	0.0130*

ns = not significantly different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).
Means within the same column under each main effect showing different superscripts are significantly different at P < 0.01.

Table 4 Effect of inclusion of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) on the performance of growing broilers compared to control (0 to 21 d old).

Diet	Level of inclusion (%)		Feed intake (kg/bird)	Feed conversion ratio
	PKM	FPKM		
1 (Control)	-		1.385 $\pm$ 0.014[a]	1.59 $\pm$ 0.10
2	10		1.372 $\pm$ 0.026[a]	1.52 $\pm$ 0.04
3	20		1.382 $\pm$ 0.019[a]	1.58 $\pm$ 0.08
4	30		1.314 $\pm$ 0.024[b]	1.56 $\pm$ 0.02
5	40		1.295 $\pm$ 0.029[bc]	1.67 $\pm$ 0.07
6		10	1.306 $\pm$ 0.023[bc]	1.59 $\pm$ 0.07
7		20	1.368 $\pm$ 0.014[a]	1.58 $\pm$ 0.04
8		30	1.267 $\pm$ 0.029[c]	1.51 $\pm$ 0.05
9		40	1.197 $\pm$ 0.009[d]	1.54 $\pm$ 0.07
Probability of statistical analysis			0.0001**	0.0511[ns]

ns = not significant different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).
Means within the same column showing different superscripts are significantly different at P < 0.01.

Table 5 Growing broiler performance (0 to 21 d) responses to levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) using orthogonal polynomial determination.

	Feed intake (kg/bird)	Average weight gain (kg/bird)	Feed conversion ratio
Performance responses to levels of PKM			
Linear	0.0002**	0.0001**	0.0051**
Quadratic	0.2387[ns]	0.3807[ns]	0.4914[ns]
Performance responses to levels of FPKM			
Linear	0.0001**	0.0966[ns]	0.1050[ns]
Quadratic	0.0001**	0.0149*	0.4669[ns]

ns = not significantly different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).

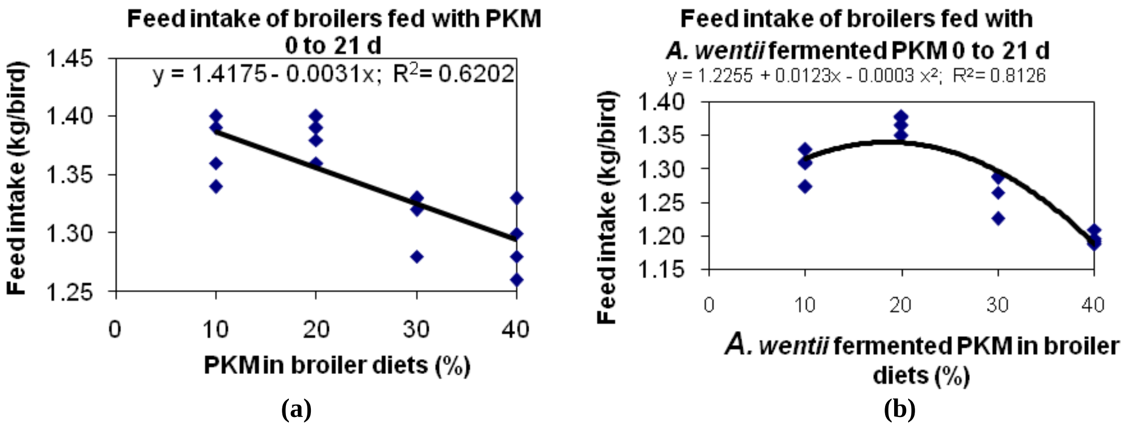


Figure 1 Relationships between levels of palm kernel meal (PKM) (a) and *Aspergillus wentii* fermented palm kernel meal (b) in rations on feed intake of broilers 0 to 21 d old.

Feed intake for 22 to 42 d old broilers fed a diet containing PKM or *A. wentii* fermented PKM was not significantly (P > 0.05) different compared with those fed a control diet (**Table 6**). Broilers fed a diet containing PKM consumed significantly more (P = 0.0001) than those fed with *A. wentii* fermented PKM. Broilers fed a diet containing 20 % of PKM or *A. wentii* fermented PKM consumed more feed than those fed at other levels, whereas broilers fed a diet containing the highest level of inclusion (40 % PKM or *A. wentii* fermented PKM) had the lowest feed intake. There was no interaction (P > 0.05) on feed intake during finishing stage. Broilers fed with a control diet had a higher average weight gain (P = 0.0001) and better feed conversion rate than broilers fed with other dietary treatments (P = 0.0001). Average weight gain of birds fed a diet containing PKM was significantly higher when compared with those birds fed an *A. wentii* fermented PKM diet (P = 0.0067). Broilers fed a diet with PKM or *A. wentii* fermented PKM higher than 20 % had significantly reduced average weight gain (**Table 6** and **Figure 2**). Significant interactions between kind of PKM and level of inclusion in the ration on average weight gain was observed (P = 0.0229). Birds fed a diet containing more than 20% PKM or *A. wentii* fermented PKM higher in the ration had significantly poorer efficiency. There was a significant interaction (P = 0.0303) between the kind and level of PKM (**Table 6**). Birds fed the 40 % fermented PKM grew slower than birds fed other diets and feed conversion rate also became poor (**Table 7**).

Table 6 Effect of main effects (kinds and levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) inclusion) on the performance of finishing broilers (22 to 42 d old).

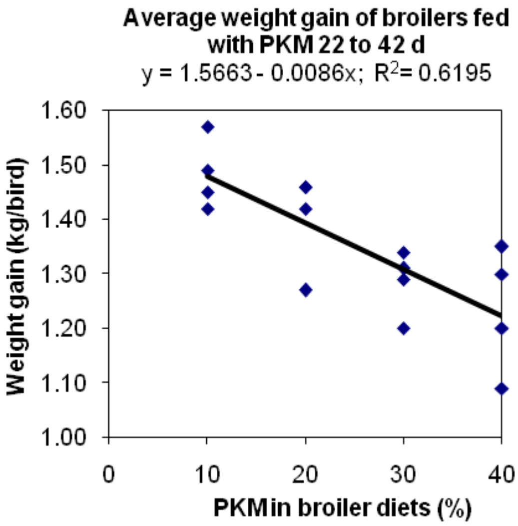
Dietary treatment	Feed intake (kg/head)	Average weight gain (kg/head)	Feed conversion ratio
Control	2.916 ± 0.105	1.588 ± 0.070	1.840 ± 0.130
Probability of statistical analysis			
Control vs others	0.4810^{ns}	0.0001**	0.0001**
Main effects:			
PKM	3.028 ± 0.113^{a}	1.351 ± 0.126^{a}	2.258 ± 0.183
FPKM	2.859 ± 0.114^{b}	1.278 ± 0.172^{b}	2.270 ± 0.265
Probability of statistical analysis	0.0001**	0.0067**	0.7682^{ns}
Levels of inclusion (%)			
10	2.960 ± 0.100^{b}	1.443 ± 0.061^{a}	2.054 ± 0.063^{a}
20	3.056 ± 0.124^{a}	1.426 ± 0.066^{a}	2.149 ± 0.119^{a}
30	2.960 ± 0.125^{b}	1.249 ± 0.084^{b}	2.390 ± 0.174^{b}
40	2.797 ± 0.090^{c}	1.140 ± 1.269^{c}	2.473 ± 0.208^{b}
Probability of statistical analysis	0.0001**	0.0001**	0.0001**
Interaction (Kinds of PKM × Levels of inclusion)			
Probability of statistical analysis	0.7187^{ns}	0.0229*	0.0303*

ns = not significantly different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).
Means within the same column under each main effect showing different superscripts are significantly different at P < 0.05.

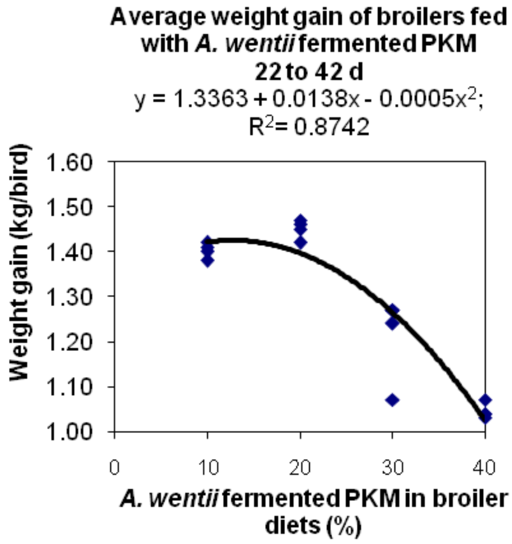
Table 7 Effect of inclusion of palm kernel meal or *Aspergillus wentii* fermented palm kernel meal on the performance of finishing broilers compared to control (22 to 42 d old).

Diet	Level of inclusion (%)		Average weight gain (kg/bird)	Feed conversion ratio
	PKM	FPKM		
1 (control)	-	-	1.588 ± 0.070[a]	1.84 ± 0.13[a]
2	10	-	1.483 ± 0.065[b]	2.06 ± 0.09[b]
3	20	-	1.403 ± 0.090[b]	2.23 ± 0.07[bc]
4	30	-	1.285 ± 0.060[c]	2.39 ± 0.12[c]
5	40	-	1.235 ± 0.012[c]	2.34 ± 0.23[c]
6		10	1.402 ± 0.017[b]	2.05 ± 0.04[b]
7		20	1.450 ± 0.022[b]	2.06 ± 0.09[b]
8		30	1.212 ± 0.096[c]	2.37 ± 0.24[c]
9		40	1.045 ± 0.017[d]	2.60 ± 0.04[d]
Probability of statistical analysis			0.0001**	0.0001**

** = highly significant difference (P < 0.01).
Means within the same column showing different superscripts are significantly different at P < 0.05.



(a)



(b)

Figure 2 Relationships between levels of palm kernel meal (PKM) (a) and *Aspergillus wentii* fermented palm kernel meal (b) in rations on average weight gain of broilers 22 to 42 d old.

The response of feed intake for broilers fed with PKM during 22 to 42 d was quadratic (P = 0.0016), while average weight gain (**Figure 2**) and feed conversion rate were linearly affected (P = 0.0007; P = 0.0080, respectively). Broilers fed with *A. wentii* fermented PKM were quadratically affected for feed intake (P = 0.0032) and average weight gain (P = 0.0011, **Figure 2**), whereas, feed conversion rate was linearly affected (P = 0.0001) (**Table 8**).

Feed intake during the entire 42 days of broilers fed a diet containing PKM or *A. wentii* fermented PKM was not significantly different (P > 0.05) compared with those fed the control diet (**Table 9**). Broilers fed a diet containing PKM consumed significantly more (P = 0.0001) than those fed with *A. wentii* fermented PKM. Broilers fed a diet containing 40 % of PKM or *A. wentii* fermented PKM consumed less feed than those fed at other levels, whereas broilers fed a diet containing 20 % PKM or *A. wentii* fermented PKM inclusion had a very significantly (P < 0.01) greater feed intake followed by birds fed a diet containing 10 and 30 % level of inclusion. There was no interaction (P > 0.05) on feed intake during the 42 day period. Broilers fed with a control diet had higher average weight gain (P = 0.0001) and better feed conversion rate (P = 0.0001) than broilers fed with other dietary treatments. Average weight gain of birds fed a diet containing PKM was significantly higher (P = 0.0025) when compared with those birds fed an *A. wentii* fermented PKM diet. Broilers fed a diet with more than 20% PKM or *A. wentii* fermented PKM very significantly decreased (P < 0.01) in average weight gain. An interaction between kind and level of PKM inclusion was observed (P = 0.0413) for the average weight gain (**Tables 9** and **10**). Birds fed a diet containing more than 20% PKM or *A. wentii* fermented PKM had significantly poor efficiency (P < 0.05) as compared with birds fed with other dietary treatments. There was no significant interaction (P > 0.05) between kind and level of PKM inclusion in the ration on feed intake and feed efficiency (**Table 9**).

Table 8 Broiler performance (22 to 42 d old) responses to levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) using orthogonal polynomial determination.

	Feed intake (kg/bird)	**Average weight gain (kg/bird)**	**Feed conversion ratio**
Performance responses to levels of PKM			
Linear	0.0020^{**}	0.0007^{**}	0.0080^{**}
Quadratic	0.0016^{**}	0.7318^{ns}	0.1500^{ns}
Performance responses to levels of FPKM			
Linear	0.0021^{**}	0.0001^{**}	0.0001^{**}
Quadratic	0.0032^{**}	0.0011^{**}	0.1062^{ns}

ns = not significantly different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).

Table 9 Effect of main effects (kinds and levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) inclusion) on the performance of broilers (0 to 42 d old).

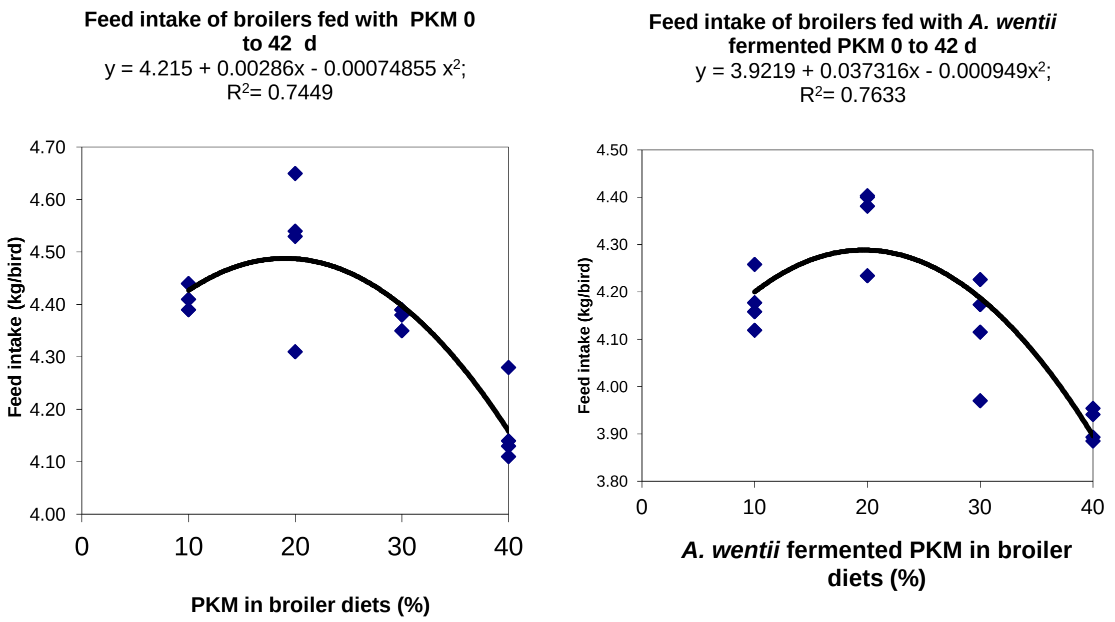
Dietary treatment	Feed intake (kg/head)	Average weight gain (kg/head)	Feed conversion ratio
Control			
Probability of statistical analysis	4.301 ± 0.969	2.460 ± 0.083	1.75 ± 0.07
Control vs others	0.3014[ns]	0.0001[**]	0.0001[**]
Main effects:			
PKM	4.369 ± 0.148[a]	2.199 ± 0.173[a]	1.99 ± 0.11
FPKM	4.143 ± 0.175[b]	2.101 ± 0.201[b]	1.98 ± 0.13
Probability of statistical analysis	0.0001[**]	0.0025[**]	0.6776[ns]
Levels of inclusion (%)			
10	4.299 ± 0.136[b]	2.303 ± 0.107[a]	1.87 ± 0.05[c]
20	4.431 ± 0.134[a]	2.294 ± 0.089[a]	1.94 ± 0.08[bc]
30	4.250 ± 0.166[b]	2.089 ± 0.082[b]	2.04 ± 0.09[ab]
40	4.043 ± 0.145[c]	1.915 ± 0.134[c]	2.12 ± 0.09[a]
Probability of statistical analysis	0.0001[**]	0.0001[**]	0.0001[**]
Interaction (Kinds of PKM × Levels of inclusion)			
Probability of statistical analysis	0.5228[ns]	0.0413[*]	0.1093[ns]

ns = not significant different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).
Means within the same column under each main effect showing different superscripts are significantly different at P < 0.01.

Table 10 Effect of inclusion of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) on average weight gain of growing chicks compared to control (0 to 42 d old).

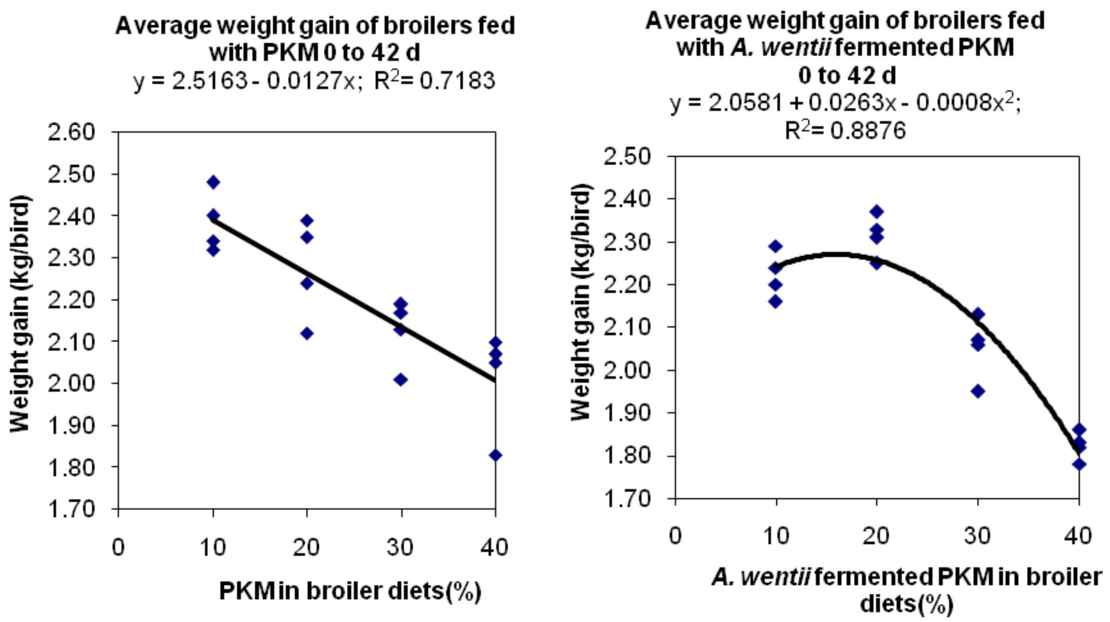
Diet	Level of inclusion (%)		Average weight gain (kg/bird)
	PKM	FPKM	
1 (control)	-	-	2.460 ± 0.083[a]
2	10	-	2.385 ± 0.072[ab]
3	20	-	2.275 ± 0.121[bc]
4	30	-	2.125 ± 0.081[bcd]
5	40	-	2.013 ± 0.123[e]
6		10	2.220 ± 0.059[bc]
7		20	2.313 ± 0.054[ab]
8		30	2.053 ± 0.075[de]
9		40	1.818 ± 0.033[f]
Probability of statistical analysis			0.0001[**]

** = highly significant difference (P < 0.01).
Means within the same column showing different superscripts are significantly different at P < 0.01.



(a) (b)

Figure 3 Relationships between levels of palm kernel meal (PKM) (a) and *Aspergillus wentii* fermented palm kernel meal (b) in rations on feed intake of broilers 0 to 42 d old.



(a) (b)

Figure 4 Relationships between levels of palm kernel meal (PKM) (a) and *Aspergillus wentii* fermented palm kernel meal (b) in rations on average weight gain of broilers 0 to 42 d old.

The response of feed intake of broilers fed a diet containing PKM was quadratically affected (P = 0.0033) during the 42 d study period (**Figure 3a**), the average weight gain of broilers fed a diet containing PKM was linearly affected (P = 0.0001, **Figure 4a**), while the feed conversion rate of broilers fed with PKM was linearly affected (P = 0.0017). Broilers fed with *A. wentii* fermented PKM was also quadratically affected (P = 0.0003) for feed intake (**Figure 3b**). The average weight gain of broilers fed with PKM over 42 days and the feed conversion rate were linearly affected (P = 0.0001; **Figure 4a**, **Table 11**). The average weight gain of broilers fed with a diet containing *A. wentii* fermented PKM was quadratically affected (P = 0.0001, **Figure 4b**), while feed conversion rate of broilers fed with PKM over 42 days was linearly affected (P = 0.0001) as was feed conversion rate (P = 0.0001, **Table 11**). Mortality was low and not related to the treatment (data not shown).

The feed cost per unit of body weight gain is shown in **Table 12**. Data show that increasing the level of PKM or *A. wentii* fermented PKM feed resulted in an increase in the cost per unit of body weight gain.

Digestibility and nutrient retention

Dry matter digestibility, nitrogen retention and apparent metabolizable energy of the PKM or *A. wentii* fermented PKM containing diets were significantly lower (P = 0.001) than the control diets. Nitrogen retention was not significantly affected (P > 0.05) by the kind of PKM but broilers fed a diet containing *A. wentii* fermented PKM had significantly (P = 0.0109) higher apparent metabolizable energy than those fed the PKM diet. At high inclusion level of PKM or *A. wentii* fermented PKM, there was a slight decrease in the digestibility of dry matter and the greatest decline was observed in nitrogen retention (**Table 13**).

Table 11 Broiler performance (0 to 42 d old) responses to levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) using orthogonal polynomial determination.

	Feed intake (kg/bird)	**Average weight gain (kg/bird)**	**Feed conversion ratio**
Performance responses to levels of PKM			
Linear	0.0004**	0.0001**	0.0017**
Quadratic	0.0033**	0.9808^{ns}	0.1909^{ns}
Performance responses to levels of FPKM			
Linear	0.0001**	0.0001**	0.0001**
Quadratic	0.0003**	0.0001**	0.0531^{ns}

ns = not significantly different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).

Table 12 Feed cost per unit of body weight gain of broiler chicken feed diets containing various levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) compared to control.

Diet	**Level of inclusion (%)**		**Dietary cost (baht/kg)**	**Feed cost unit gain (baht/kg)**		
	PKM	**FPKM**		**0 - 3 week**	**3 - 6 week**	**0 - 6 week**
1 (Control)	-	-	12.50	19.84±1.19	23.01±1.63	21.88±0.93
2	10	-	12.37	18.75±0.49	25.47±1.10	22.94±0.82
3	20	-	12.19	19.30±0.96	27.20±0.87	24.18±0.64
4	30	-	11.96	18.66±0.25	28.58±1.40	24.67±0.84
5	40	-	11.84	19.75±0.81	27.74±2.76	24.59±1.48
6	-	10	12.40	19.78±0.89	25.40±0.46	23.34±0.32
7	-	20	12.28	19.44±0.48	25.30±1.07	23.14±0.91
8	-	30	12.14	18.33±0.63	28.74±2.86	24.40±1.27
9	-	40	12.02	18.53±0.83	31.30±0.50	25.91±0.34

Table 13 Effect of main effects (kinds and levels of palm kernel meal (PKM) or *Aspergillus wentii* fermented palm kernel meal (FPKM) supplementation) on dry matter digestibility (DMD), nitrogen retention (NR) and apparent metabolizable energy (AME) of growing broilers at 3 week of age (DM basis).

Dietary treatment	Dry matter digestibility (%)	Nitrogen retention (%)	Apparent metabolizable energy (kcal/kg)
Control	77.00 ± 1.00	68.09 ± 1.65	3,674 ± 98.51
Probability of statistical analysis			
Control vs others	0.0001**	0.0001**	0.0001**
Main effects:			
Kinds of PKM			
PKM	61.40 ± 4.30b	42.64 ± 6.88	3,096 ± 262.80b
FPKM	66.25 ± 10.82a	42.44 ± 15.45	3,218 ± 253.53a
Probability of statistical analysis	0.0001**	0.856ns	0.0109*
Levels of inclusion (%)			
10	65.50 ± 6.56a	54.81 ± 8.30a	3,243 ± 351.14b
20	67.33 ± 11.69a	37.10 ± 5.43b	3,005 ± 77.36c
30	61.00 ± 2.94b	36.85 ± 3.79b	3,138 ± 207.30b
40	60.16 ± 9.47b	38.30 ± 13.09b	3,311 ± 290.48a
Probability of statistical analysis	0.0001**	0.0001**	0.0002**
Interaction (Kinds of PKM × Levels of inclusion)			
Probability of statistical analysis	0.0001**	0.0001**	0.0001**

ns = not significantly different (P > 0.05); * = significantly different (P < 0.05); ** = highly significant difference (P < 0.01).
Means within the same column under each main effect showing different superscripts are significantly different at P < 0.05.

The result in the starter period further showed that the broilers on PKM or *A. wentii* fermented PKM diets consumed significantly more feed than those on the control diet without PKM. For the second period, feed intake of birds was similar for birds fed a diet containing PKM and *A. wentii* fermented PKM group. The use of *A. wentii* fermented PKM in the diet depressed feed intake significantly compare with those fed a diet containing PKM throughout the feeding trial. At 20 % inclusion, feed intake was significantly greater than those fed at other levels, mainly because the apparent metabolizable energy was lower than other levels. In theory, birds adjust their feed intake to obtain a constant energy intake [13]. Broilers fed a diet with *A. wentii* fermented PKM had significantly depressed body weight gain. The interaction of feed intake and average weight gain detected probably due to different response, i.e. average weight gain of 42 day old birds fed a diet containing PKM was linearly affected but birds fed a diet containing *A. wentii* fermented PKM was quadratic. The poor performance of the birds fed PKM or *A. wentii* fermented PKM at high levels may be due to the lower crude protein digestibility. For the results of digestibility and nutrient retention, dry matter digestibility was comparable with the report of Ezieshi and Olomu [14] but crude protein was slightly lower. Osei and Amo [15] fed broilers with different levels of palm kernel meal in isonitrogenous diets and found no significant differences in body weight and feed consumption up to 8 weeks old. In contrast, feed conversion efficiency significantly declined as palm kernel meal levels reached 12.5 % of the diet or higher. Yeong *et al.* [16] fed growing chickens with various levels of palm kernel meal in isonitrogenous, isocaloric diets. They found no significant differences in daily feed intake and daily weight gain. However, the feed conversion ratio significantly improved when diets containing lower levels of palm kernel meal were fed. Maliwon [17] stated that performance of broilers from 0 - 3 and 3 - 6 weeks old, weight gain of broilers fed 20 % palm kernel cake on available amino acids basis was significantly greater than those fed control diets. Chauysongkram [18] fed broilers with diets containing 0 - 40 % palm kernel meal (solvent extracted) in 0 - 3 wk of age showed that the body weight of chickens fed a diet containing more than 20 % palm kernel meal were significantly lower than other groups. Body weight gain and feed conversion rate of chickens fed a diet containing 40 % palm kernel meal were significantly lower than others in the second period (3 - 6 weeks old). For apparent protein digestibility at 0 - 3 weeks old, broilers fed a control diet was significantly higher than those fed diets containing palm kernel meal, but there was no significant difference with amino acid and energy supplemented high palm kernel meal diets. During 3 - 6 weeks old, there was no significant difference. In the feeding trial, at 0 - 7 weeks old, body weight gain and carcass percentage of broilers fed high palm kernel meal diets were slightly lower than the control. Broilers fed a control diet had significantly higher abdominal fat than those fed high (30 %) palm kernel meal [19].

The metabolizable energy of palm kernel meal varied widely, from at least 1,479.41 kcal/kg [20] to 2,654 kcal/kg [21]. This may be due to the oil content remaining in the feedstuff, and also due to differences in the oil extraction process. The different ages of birds probably also contributes to the differences found in the values of metabolizable energy. Ezieshi and Olomu [21] reported differences in sources of palm kernel meal on proximate analysis values, the crude protein content for Okomu, Presco and Envoy PKM were 14.50, 16.60 and 19.24 % respectively, while Envoy PKM resulted in the highest crude fiber value (17.96 %). The crude fat content varied between 1.3 % (Envoy PKM) and 9.48 % (Okomu PKM). The results of the metabolizable energy showed that Okomu PKM gave the highest AME value of 2,654 kcal/kg while Envoy PKM gave the lowest value of 1,817 kcal/kg. Presco PKM gave an intermediate value of 2,423 kcal/kg. They concluded that Okomu and Presco PKM which were mechanically processed resulted in higher metabolizable energy than the Envoy PKM which was solvent extracted. Mechanical extraction (expeller) resulted in higher residual oil (~ 8 - 10 %) in the cake than the solvent extraction process which resulted in no more than 1 % residual oil.

Previous recommendation for using palm kernel meal indicated that 20 % could be given to broilers without any negative effects on the performance of birds [22]. Onwudike [23] investigated the possible inclusion of palm kernel meal in broiler starter and finisher diets and reported that 28 % followed by 35 %, respectively, could be used without any ill effects. Later reports suggested that diets containing up to 40 % palm kernel meal could be fed to broilers when methionine and lysine were added [19,24]. Amino acids and metabolizable energy are two important considerations in the diet formulation, particularly for a diet containing a high fiber ingredient such as palm kernel meal. Amino acid content of palm kernel meal is also low. Amino acid availability appears to be rather high, exceeding 83 %, except for cysteine [4]. *A. wentii* fermented PKM depressed availability of lysine and some other amino acids. However, palm kernel meal is regarded as an excellent source of arginine because of its high content (1.81 and 1.55 % for PKM and *A. wentii* fermented PKM, respectively) and high availability (95 and 91 % for PKM and *A. wentii* fermented PKM, respectively) [4]. It has been reported by Chamruspollert *et al.* [25] and [26] that the nutritional requirements for arginine, methionine and lysine are interrelated. The inclusion of palm kernel meal in the diet should be supplemented with either synthetic lysine or a high lysine feedstuff to balance these amino acids. Balnave *et al.* [27] found that arginine: lysine ratio of 1.03 gave better results for birds kept from three to seven weeks under a temperature of 32 °C. The requirement for methionine increased as levels of arginine increased [28]. The importance of considering methionine and lysine when palm kernel meal is used in large quantities in the broiler rations.

Feed intake of birds fed palm kernel meal based diets is usually higher than for a basal diet. This is probably due to its faster passage rate of feed in the digestive tract. Sundu *et al.* [29] compared the bulk densities of many poultry feedstuffs and found that the bulk density and the water holding capacity of palm kernel meals were 0.57 g/cm^3 and 2.93 g water/g feed, respectively. These values were very close to soybean meal. Low bulk density and high water holding capacity are believed to impair feed intake. The water intake of birds fed palm kernel meal based diets is also increased [19] and there is increased moisture content of excreta [30]. The decrease in the digestibility of the diet was not associated with the viscosity of the diet as the inclusion of palm kernel meal decreased jejunal digesta viscosity [24]. The decrease in feed digestibility may be due to the fact that broiler chickens have a limited ability to digest dietary fiber. The lignin content of the nut shells in palm kernel meal is a contributing factor to its low digestibility. The reduction in lipid and mineral digestibility is caused by dietary fiber [31-33]. In this study, all experimental diets were adjusted to be isocaloric by using palm oil, for the control experimental diet 1.60 %, additional palm oil in experimental diets adjust to meet the AME requirement was up to 9.4 % in the starter diet. There was a significant decrease in dry matter digestibility of feed with increasing level of PKM or *A. wentii* fermented PKM above 20%. Htin [34] found that the diets rich in saturated fatty acids increased abdominal fat and crude fat percent of thigh meat of chicks as compared to diets rich in polyunsaturated fatty acids. The digestibility of a dietary fat depends on the chemical nature of its constituent fatty acids. Fats rich in unsaturated fatty acids are better digested and absorbed than saturated fats. Increased sunflower seed fiber content and decreased CF digestibility did not affect the ether extract (EE), nitrogen, and other nutrient retention in the starter diet [35]. Significant reduction in fat digestibility was observed with increasing storage period of rice bran [36].

Previous studies on PKM fermented with *Aspergillus niger* were reported by Khin [37] and Mirnawati *et al.* [38], but still have limited use in poultry rations. Khin [37] noted that the feeding trial carried out in broilers (maximum level of *A. niger* fermented palm kernel cake 20 %) showed no beneficial effect using the fermented substrate as a ration component in the poultry feed. The information obtained in that study could be beneficial in the understanding of the biochemical changes that occur in PKC during solid state fermentation (SSF) with *A. niger*. Since its inclusion up to 40 % did not have a negative effect on carcass yield of broilers. Response of gizzard for broiler fed with *A. wentii* fermented PKM was a linear increasing while the abdominal fat pad linearly decreased with increasing levels of PKM or *A. wentii* fermented PKM [39].

Conclusions

The nutritive value of fermented PKM was enhanced by solid-state fermentation with *A. wentii*, growth performance of broilers showed no benefits in using the fermented substrate as a ration component in broiler feed. Levels of PKM or *A. wentii* fermented PKM higher than 20 % very significantly decreased feed intake and average weight gain also decreased, while feed efficiency declined. Birds consumed more feed to maintain requirements and this is affected by the lower apparent metabolizable energy. Feed intake of growing broilers (0 to 21 d old) fed with PKM linearly decreased followed by a quadratic response during the finishing period (22 to 42 d of age) but broilers fed with *A. wentii* fermented PKM showed a quadratic response throughout the 42 day feeding trial. Response for inclusion of PKM showed a negative linear decrease for average weight gain, whereas *A. wentii* fermented PKM was quadratic. Data showed that broilers performance response when fed with PKM linearly decreased while when fed with *A. wentii* fermented PKM a quadratic and slow decrease was observed. During the growing period not more than 20% PKM or *A. wentii* fermented PKM, or 30 % in the finishing period could be used. However, at 20 % in the diet broilers fed with *A. wentii* fermented PKM tended to have better performance than those fed PKM. The poor performance of the birds fed PKM or *A. wentii* fermented PKM at high levels may be due to the higher crude fiber content and the lower nitrogen retention. However, its inclusion up to 40 % did not have a negative effect on the carcass yield of broilers.

Acknowledgements

This research was supported by Walailak University. The authors also would like to thank staff of Center for Scientific and Technological Equipments (WU) for facilities help.

References

[1] CM Grieshop, DE Reese and GC Jr Fahey. Non starch polysaccharides and oligosaccharides in swine nutrition. *In*: AJ Lewis and LL Southern (ed.). *Swine Nutrition*. CRC Press, New York, 2000, p. 107-30.

[2] KE Bach Knudsen. Carbohydrate and lignin contents of plant materials used in animal feeding. *Anim. Feed Sci. Technol.* 1997; **67**, 319-38.

[3] EM Dusteshorft, MA Posthmus and AGJ Voragen. Non-starch polysaccharides from sunflower (*Helianthus annus*) meal and palm-kernel (*Elaeis guineensis*) meal - Investigation of the structure of major polysaccharide. *J. Sci. Food Agric.* 1992; **59**, 151-60.

[4] N Muangkeow and C Chinajariyawong. Determination of true amino acid digestibility and metabolizable energy in fermented palm kernel meal with *Aspergillus wentii* TISTR 3075 for chickens. *Walailak J. Sci. & Tech.* 2009; **6**, 231-41.

[5] FB Iluyemi, MM Hanafi, O Radziah and MS Kamarudin. Nutritional evaluation of fermented palm kernel cake using red tilapia. *African J. Biotech.* 2010; **9**, 502-7.

[6] NRC. *Nutrient Requirements of Poultry*. 9th Revised Edition, National Academy Press, Washington D.C., 1994, p. 27.

[7] TA Scott and F Boldaji. Comparison of inert makers [chromic oxide or on soluble ash (Celite^{TM})] for determining apparent metabolizable energy of wheat- or barley-based broiler diets with or without enzymes. *Poultry Sci.* 1997; **76**, 594-8.

[8] PJ Lammers, BJ Kerr, MS Honeyman, K Stalder, WA Dozier III, TE Weber, MT Kidd and K Bregendahl. Nitrogen-corrected apparent metabolizable energy value of crude glycerol for laying hens. *Poultry Sci.* 2008; **87**, 104-7.

[9] AOAC. *Official Method of Analysis*. 18th ed. Association of Official Analytical Chemists International. Gaitherburg, Maryland, 2005, p. 4, 1-61.

[10] ASTM. *Standard Test Method for Gross Calorific Value of Coal and Coke*. D5865-04, West Conshohocken, 2004, p. 519-29.

[11] RC Damon and WR Harvey. *Experimental Design, ANOVA, and Regression*. Harper and Row, Publishers, New York, 1987, p. 508.

[12] K Hinkelmann and O Kemptorne. *Design and Analysis of Experiments: Volume I Introduction to Experimental Design*. 2nd edition, Wiley-Interscience, New Jersey, 2008, p. 631.

[13] S Leeson, L Caston and JD Summers. Broiler response to diet energy. *Poultry Sci.* 1996; **75**, 529-35.

[14] EV Ezieshi and JM Olomu. Nutritional evaluation of palm kernel meal types: 2. Effect on live performance and nutrient retention in broiler chicken diets. *African J. Biotech.* 2008; **7**, 1171-5.

[15] SA Osei and J Amo. Palm kernel cake as a broiler feed ingredient. *Poultry Sci.* 1987; **66**, 1870-3.

[16] SW Yeong, TK Mukherjee and RI Hutagalung. The nutritive value of palm kernel cake as a feedstuff for poultry. *In*: Proceedings of the National Workshop on Oil Palm By-Product Utilization, Kuala Lumper, 1981, p. 100-7.

[17] P Maliwon. Nutritive value of palm kernel cake and its utilization in broiler rations. Master Thesis, Prince of Songkla University, Songkla, Thailand, 2000.

[18] T Chauysongkram. Apparent metabolizable energy value and utilization of palm kernel meal in broiler rations. Master Thesis, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand, 2004.

[19] S Panigrahi and CJ Powell. Effects of high inclusion of palm kernel meal in broiler chick diets. *Ani. Feed Sci. Technol.* 1991; **34**, 37-47.

[20] FY Chin. Utilization of palm kernel cake (PKC) as feed in Malaysia. *Asian Livest. Mag*. 2002; **October - December**, 16-23.

[21] EV Ezieshi and JM Olomu. Nutritional evaluation of palm kernel meal types: 1. Proximate composition and metabolisable energy values. *African J. Biotech.* 2007; **6**, 2484-6.

[22] SW Yeong. The nutritive value of palm oil by-products for poultry. *Proc. First Asia-Aus. Ani. Sci.* 1980; **45**, 17.

[23] OC Onwudike. Palm kernel as a feed for poultry. 3. Replacement of ground nut cake

by palm kernel meal in broiler diets. *Ani. Feed Sci. Technol.* 1986; **16**, 195-202.
[24] B Sundu, A Kumar and J Dingle. Response of birds fed increasing levels of palm kernel meal supplemented with enzymes. *Aus. Poult. Sci. Symp.* 2005; **17**, 227-8.
[25] M Chamruspollert, GM Pesti and RI Bakalli. Dietary interrelationships among arginine, methionine, and lysine in young broiler chicks. *Br. J. Nutr.* 2002; **88**, 655-60.
[26] D Balnave and J Barke. Re-evaluation of the classical dietary arginine: lysine interaction for modern poultry diets: a review. *World's Poult. Sci. J.* 2002; **58**, 275-89.
[27] D Balnave, J Hayat and J Brake. Dietary arginine: lysine ratio and methionine activity at elevated environmental temperatures. *J. Appl. Poult. Res.* 1999; **8**, 1-9.
[28] M Chamruspollert, GM Pesti and RI Bakalli. Influence of temperature on the arginine and methionine requirements of young broiler chicks. *J. Appl. Poult. Res.* 2004; **13**, 628-38.
[29] B Sundu, A Kumar and J Dingle. The importance of physical characteristics of feed for young broilers. *Queensland Poult. Sci. Symp.* 2005; **12**, 63-75.
[30] OC Onwudike. Palm kernel as a feed for poultry 2. Diets containing palm kernel meal for starter and grower pullets. *Ani. Feed Sci. Techn.* 1986; **16**, 187-94.
[31] CHM Smits and G Annison. Non-starch plant polysaccharides in broiler nutrition - towards a physiologically valid approach to their determination. *World's Poult. Sci. J.* 1996; **52**, 203-11.
[32] H Jorgensen, X Zhao, KE Bach Knudsen and B Eggum. The influence of dietary fibre source and level on the development of the gastrointestinal tract, digestibility and energy metabolism in broiler chickens. *Br. J. Nutr.* 1996; **75**, 379-95.
[33] PJ Van der Aar, GC Fahey, SC Ricke, SE Allen and LL Berger. Effects of dietary fibers on mineral status of chicks. *J. Nutr.* 1983; **113**, 653-61.
[34] NN Htin. 2006, Effect of Dietary of Fatty Acid Saturation on Broiler Chickens Subjected to High Ambient Temperatures, Ph.D. Dissertation. University of Putra, Malaysia, Selangor Darul Ehsan, Malaysia.
[35] RK Selvaraj and MR Purushothaman. Nutritive value of full-fat sunflower seeds in broiler diets. *Poultry Sci.* 2004; **83**, 441-6.
[36] A Mujahid, M Asif, I ul Haq, M Abdullah and AH Gilani. Nutrient digestibility of broiler feeds containing different levels of variously processed rice bran stored for different periods. *Poultry Sci.* 2003; **82**, 1438-43.
[37] HS Khin. 2004, Evaluation of Solid State Fermentation by *Aspergillus niger* to Improve the Nutritive Value of Palm Kernel Cake for Broilers. Ph.D. Dissertation, University of Putra, Malaysia.
[38] Mirnawati, Y Rizal, Y Marlida and IP Kompiang. The role of Humic acid in palm kernel meal fermented by *Aspergillus niger* for poultry ration. *Pakistan J. Nurti.* 2010; **9**, 182-5.
[39] C Chinajariyawong and N Muangkeow. Carcass traits and visceral organs of broiler chickens fed palm kernel meal or *Aspergillus wentii* TISTR 3075 fermented palm kernel meal. *Walailak J. Sci. & Tech.* 2011; **8**,175-85.