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EFFECTS OF FERMENTED PALM KERNEL CAKE IN HUMIC ACID AND LIMESTONE SOLUTIONS ON THE PERFORMANCE OF BROILER CHICKENS

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ABSTRACT: Palm kernel meal is a by-product used very sparingly in poultry feed, due to its low nutritional value and gravelly appearance which could be improved by physical or chemical treatments. The aim of this study was to assess the effect of palm-kernel meal fermentation period on its nutritional value and growth performances of broiler chickens. The treatment consisted of fermenting palm kernel meal in a solution of humic acid (HA) or limestone, for 0, 2, 4 and 6 days. A control ration without palm kernel meal (R0) was compared to rations containing 15% unfermented palm kernel cake (R0+) and 15% fermented palm kernel cake in humic acid and limestone solutions. Each experimental ration was randomly assigned to 8 chicks in 4 experimental units of 02 chicks each, repeated 4 times per a 2×3 factorial design (2 fermentation modes and 3 fermentation period). The main results showed that fat content (13.04%) and metabolizable energy (5314 Kcal/kg DM) of palm kernel meal were higher when fermented in humic acid for 6 days. Fermentation in the basic solution for the same period (6 days) increased protein (13.52%) and cellulose (24.21%) contents. Whatever the fermentation mode, the digestive utilization coefficient of dry matter, organic matter, crude protein and crude cellulose increased with the fermentation period. Fermentation mode and period had no significant effect on growth performance. However, growth characteristics tended to improve with fermentation period. In conclusion, fermentation of palm kernel in humic acid and limestone solutions improved significantly ($P<0.05$) the digestibility of all feed components, enabling chickens to take advantage of the nutrients for better growth performances.

Keywords: Chemical composition, Digestibility, Fermentation, Humic acid, Metabolizable energy, Palm kernel meal.

INTRODUCTION

The nutrition policy of most states in the world relies on eggs and poultry meat to cover the protein needs of populations due to their availability, affordable price and lack of taboo about poultry products. The focus on poultry requires the intensification of production systems, which in turn leads to a high demand for feed resources capable of covering the protein and energy requirements of broilers (Alshelmani et al., 2021). Poultry farming relies heavily on conventional feed resources such as corn and soybean meal, which respectively account for 60-70% and 15-30% of broilers rations (Kana et al., 2015). This dependence on conventional resources comes up against several crucial problems such as, fluctuating prices and above all competition between animals, agri-food industries and humans for corn and soybean in particular. Cameroon produces a wide range of agro-industrial by-products such as wheat bran, rice bran and palm kernel meal, which are used in very limited quantities in poultry feed. This limitation is due to the presence of a multitude of compounds such as non-starch polysaccharides (NSPs) like xylan and mannan found in palm kernel meal, which at a certain level depress bird growth (Aftab and Bedford, 2018). The non-starch polysaccharides increased viscosity of the contents of the birds' small intestine, which induced the excessive dehydration of the bird, materialized by the increased water content of the droppings (Aftab and Bedford, 2018; Ramiah et al., 2019; Alshelmani et al., 2021).

Palm kernel meal is a by-product derived from the extraction of oil from palm kernels. This by-product (Aderolu et al., 2006; Faridah et al., 2020; Prasetya et al., 2021), widely available in Cameroon and inexpensive, is used in very large quantities in pig feed, and rather sparingly in poultry feed due to its high fiber content (24.25%) and low protein content (17-22%) and very low biological value of its protein (Yemdjie et al., 2020). This meal is an important source of crude energy (4939 kcal/kg DM) and metabolizable energy (2570 Kcal/Kg DM; Meffeja et al., 2003). It has a gravelly appearance and coarse texture (Alshelmani et al., 2016; 2017; Zamani et al., 2017; Mirnawati et al., 2018; 2019). These characteristics limit its use in poultry feed in general and broiler feed in particular.

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The addition of amino acids (Yemdjie et al., 2020), exogenous enzymes (Sharmila et al., 2014) and solid-state fermentation by cellulolytic microorganisms (Alshelmani et al., 2017) or organic compounds such as humic acid (Mirnawati et al., 2019) could improve the nutritional value and digestibility of palm kernel meal. Mirnawati et al. (2018) reported that mushroom-acid combination could enable this by-product to be better valorized in poultry feed. Humic acid stimulates the growth of microbes that facilitate the conversion of fiber into glucose accessible to enzymes in the digestive tract of birds (Sukaryana et al., 2010). The present study was designed to test the hypothesis that certain organic compounds improve the nutritional value of poor feed resources. The aim was to assess the effect of humic acid (HA) and limestone fermentation period on palm kernel meal nutritional value and growth performances of broiler chickens.

MATERIALS AND METHODS

Study area

The study was done at the Teaching and Research Farm (TRF) of the University of Dschang. The TRF is located at 05°26' North latitude, 10°26' East longitude and at an altitude of 1420 m. The prevailing climate is equatorial characterized by two seasons; a rainy season that goes from mid-March to mid-November and a dry season that covers the rest of the year. Precipitation varies between 1500 and 2000 mm per year. The average temperature is around 21°C, and the average relative humidity is 76.8%.

Ethical considerations

The present study has been performed in agreement with the guidelines of ethical standards from the Department of Animal Science of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang, Cameroon.

Processing of palm kernel meal

The palm kernel cake was soaked in an acidic and basic solution in the proportions 1/2 (1 kg of meal for 2 liters of solution) then fermented for 2, 4 and 6 days. The acidic solution consisted of dissolving 2 g of humic acid (HA) in one liter of water, and the basic solution consisted of dissolving 30 g of limestone in one liter of water. The fermented meal from these solutions was sun-dried for 5 days, and samples were taken for the analysis organic matter, crude cellulose and crude protein content.

Birds and experimental rations

A total of 64 chicks (32 males and 32 females), 21 days old, with an average weight of 758.31 ± 40.6g were housed in 32 wire cages, with 8 chicks per cage for 4 weeks trial. Eight experimental rations were formulated and each was randomly assigned to 4 experimental units consisting of 08 birds (4 males and 4 females) each in a 2×3 factorial design (2 fermentation modes and 3 fermentation period). An antistress (Tetracoli®) was administered to the chicks for three consecutive days through drinking water as soon as they arrived at the farm. Anticoccidial (Vetacox®) and vitamins (Amintotal®) were administered in drinking water for three consecutive days each week. Two nutrient-balanced control rations were formulated, one without palm kernel meal (R0) and the other contained 15% unfermented palm kernel meal (R0+). The other 06 rations contained 15% palm kernel meal fermented in acidic and basic solution for 2, 4 and 6 days respectively (Table 1).

Feed component digestibility

Feed was weighed and served each morning to the birds, the refusals and faeces from each experimental unit were collected and weighed the next day at the same time during 4 days. The faeces samples were dried in an oven at 50°C until constant weight for dry matter (DM), organic matter (OM), crude cellulose (CC), Neutral Detergent Fiber (NDF) and crude protein (CP) were analysed as described by AOAC (1990). The apparent digestive utilization coefficients (aDUC) of DM, OM, CC, NDF and CP of the experimental rations were calculated according to the following formula:

$$\mathbf{aDUC}\ (\%) = \frac{\text{Quantity ingested (g)} - \text{Quantity excreted (g)}}{\text{Quantity } ingested\ (g)} \times 100$$

Growth performances

Feed intake was determined by the difference between the amount of feed served and leftovers at the end of the week. Broilers were weighed at the beginning of the experiment and a weekly basis thereafter using an electric scale at 0.1 g sensitivity. Average weekly weight gain was obtained by doing the difference between two consecutive weekly weights. Feed conversion ratio was obtained by dividing the amount of feed intake by the weight gain of the same week.

Statistical analysis

Collected data were submitted to a 2-ways analysis of variance (ANOVA) (2 fermentation modes and 3 fermentation periods). Duncan's test was used to separate treatments means a 5% significance when there was a significant difference level using SPSS 22.0 (Statistical Package for Social Sciences). Results were expressed as mean ± standard deviation.

$x_{ijk} = \mu + a_i + \beta_j + e_{ijk}$

Which, x_{ij} = observation on animal j having received treatment I; μ = General average of the observation; a_i = Effect of fermentation mode; β_j = Effect of fermentation duration of palm kernel cake in the ration; e_{ij} = Residual error due to the animal having received treatment i.

Table 1 - Composition of experimental rations

Ingredients \ Experimental rations	Control		Acid solution			Basic solution		
	R0	R0+	A2	A4	A6	B2	B4	B6
Maize	68	59	59	59	59	59	59	59
Soybean meal	14	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Palm kernel meal	0	15	15	15	15	15	15	15
Fish meal	5	6	6	6	6	6	6	6
Blood meal	5	4	4	4	4	4	4	4
Palm oil	2	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Premix 5%	5	5	5	5	5	5	5	5
Lysine	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Methionine	0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Oyster shell	1	1	1	1	1	1	1	1
Calculated chemical composition								
Metabolizable energy (Kcal/Kg)	3164.92	2949.23	3024.73	3021.01	3012.18	2937.44	3084.35	3083.89
Crude protein (%)	20.41	18.79	19.00	19.24	19.20	19.13	19.18	19.28
Crude cellulose (%)	2.16	6.77	6.15	6.00	6.4	6.46	5.39	5.35
Lipid (%)	4.93	6.68	7.00	6.8	7.19	6.45	7.09	7.02
Calcium (%)	1.63	1.24	1.24	1.24	1.24	1.24	1.24	1.24

*MNVC5%: Mineral, nitrogen and vitamin complex: crude protein =40%, Lysine=3.3%, Methionine=2.4%, Calcium=8%, Phosphorus=2.05%, Metabolisable Energy=2078 Kcal/Kg. ME =Metabolisable Energy; R0= Control ration without palm kernel meal; R0+ =Ration containing 15% untreated palm kernel meal; A2= Ration containing 15% palm kernel meal fermented in acidic medium for 2 days; A4= Ration containing 15% palm kernel meal fermented in acidic medium for 4 days; A6= Ration containing 15% palm kernel meal fermented in acidic medium for 6 days;B2= Ration containing 15% palm kernel meal fermented in basic medium for 2 days; B4= Ration containing 15% palm kernel meal fermented in basic medium for 4 days;B6= Ration containing 15% palm kernel meal fermented in limestone medium for 6 days.

RESULTS

Effects of fermentation mode and period on the chemical composition of palm kernel cake

Table 2 summarizes the chemical composition of palm kernel cake fermented in acidic and basic solutions for 2, 4 and 6 days. Concerning the fermentation period, the fermentation mode had no significant (P>0.05) effect on the proximate composition of palm kernel cake. Irrespective of fermentation mode, crude protein, ash, lipid, crude cellulose and metabolizable energy content of palm kernel meal increased significantly (P<0.05) with increasing fermentation period. Crude cellulose and NDF content of palm kernel meal decreases significantly (P<0.05) with increasing fermentation period irrespective of the fermentation solution.

Figure 1, showing the regression of crude protein, crude cellulose and NDF as a function of fermentation time, revealed that in humic acidic solution, the increase in crude protein content and the significant linear decrease (p=0.0001) in crude cellulose and NDF are essentially linked to fermentation period (96%; 99%; 97% respectively). Similarly, the same figure shows that under basic solution, the linear increase in crude protein content and the decrease in crude cellulose and NDF content are essentially linked (96%; 90%; 99%) to the increase in fermentation period.

Effects of the fermentation mode and period of palm kernel meal on the feed component digestibility

The effects of the mode and period of palm kernel meal fermentation on the apparent digestibility of feed components are summarized in Table 3. Fermentation had an improving effect on the digestibility of feed components, regardless of the solution or medium used. Although not significant (P>0.05), fermentation tended to increase the digestibility of crude protein and NDF with increasing fermentation period. Apparent digestibility of dry matter, organic matter and crude cellulose increased linearly and significantly (P<0.05) with the fermentation period. With respect to the fermentation period, there was no significant (P>0.05) difference between fermentation modes.

Figure 2 shows the regression of feed components digestibility on the fermentation period of palm kernel meal. It is appear that the improvement in digestibility of crude protein, crude cellulose and NDF depends at 97.91%, 95.07% and 99.12% respectively on the fermentation period in humic acid solution, and respectively by 95.35%, 78.17% and 95.04% on the duration in limestone solution.

Effects of palm kernel meal fermentation mode and period on broiler growth performances

Table 4 summarizes the effects of palm kernel meal fermentation mode and duration on broiler growth performances. The fermentation mode and period did not have a significant effect (P>0.05) on feed intake, weight gain and feed conversion ratio of broilers at the finisher phase. However, though not significant, with respect to the control ration containing unfermented palm kernel, feed intake, weight gain and live weight increased linearly with the fermentation period, while feed conversion ratio moved in the opposite direction. Irrespective of fermentation mode, growth parameters recorded with palm kernel meal fermented for 6 days were almost similar to those recorded with the control ration without palm kernel (R0). For the same duration of fermentation, the fermentation mode had no significant (P>0.05) effect on broiler growth parameters.

Table 2 - Variation in the chemical composition of palm kernel meal according to the fermentation mode and period

Fermentation mode	Fermentation period (days)	0	2	4	6	P-value
Dry matter (%)	Acid	89.34 ± 0.87^{bc}	88.59 ± 0.17^{c}	91.27 ± 0.02^{a}	90.16 ± 0.32^{b}	0.001**
	Basic	89.34 ± 0.87	89.88 ± 0.04	88.56 ± 0.31	88.80 ± 0.50	0.059 ^{NS}
	P-value	1.000	0.211	0.135	0.577	
Organic matter (%DM)	Acid	96.88 ± 0.13^{a}	96.38 ± 0.01^{b}	96.88 ± 0.09^{a}	97.1 ± 0.01^{a}	0.0001***
	Basic	96.88 ± 0.13^{a}	92.67 ± 0.01^{d}	94.63 ± 0.08^{c}	94.80 ± 0.06^{b}	0.0001***
	P-value	1	0.561	0.863	0.176	
Crude protein (%DM)	Acid	10.28 ± 0.10^{d}	11.63 ± 0.02^{c}	13.23 ± 0.00^{a}	13.01 ± 0.05^{b}	0.0001***
	Basic	10.28 ± 0.10^{d}	12.49 ±0.01^{c}	12.86 ± 0.05^{b}	13.52 ± 0.08^{a}	0.0001***
	P-value	1.000	0.259	0.089	0.510	
Crude cellulose (%DM)	Acid	33.68 ± 0.33^{a}	31.19 ± 0.11^{b}	29.53±0.06^{c}	28.49 ± 0.01^{d}	0.0001***
	Basic	33.68 ± 0.33^{a}	31.58 ±0.02^{b}	24.48 ± 0.09^{c}	24.21 ± 0.14^{c}	0.0001***
	P-value	1	0.167	0.627	0.130	
Neutral Detergent Fibre (%DM)	Acid	78.99 ± 0.04^{a}	72.03 ± 0.14^{b}	70.65 ± 0.02^{c}	69.70 ± 0.68^{d}	0.0001***
	Basic	78.99 ± 0.04^{a}	76.33 ±0.27^{b}	74.48 ± 0.49^{c}	71.1 ± 0.40^{d}	0.0001***
	P-value	1	0.425	0.123	0.528	
Ash (%DM)	Acid	3.12 ± 0.13	2.99 ± 0.01	3.63 ± 0.01	4.47 ± 2.31	0.457^{NS}
	Basic	3.12 ± 0.13	5.20 ± 0.06	5.38 ± 0.08	5.33 ± 1.99	0.066^{NS}
	P-value	1	0.176	0.123	0.606	
Fat (%DM)	Acid	9.64 ± 0.09^{d}	10.50 ± 0.01^{c}	11.68 ± 0.02^{b}	13.04 ± 0.05^{a}	0.0001***
	Basic	9.64 ± 0.09^{c}	8.16 ± 0.01^{d}	11.92 ± 0.07^{b}	12.42 ± 0.05^{a}	0.0001***
	P-value	1	0.259	0.129	0.620	
Gross energy (Kcal/Kg DM)	Acid	5090.60 ± 7.38^{c}	5090.98 ± 0.25^{c}	5224.67 ± 0.09^{b}	5314.42 ± 2.52^{a}	0.0001***
	Basic	5090.60 ± 7.38^{c}	4811.94 ± 0.39^{d}	5117.01 ± 0.73^{b}	5140.14 ± 1.89^{a}	0.0001***
	P-value	1	0.581	0.157	0.709	
Metabolizable energy (Kcal/kg DM)	Acid	1423 ± 34.18^{c}	1843 ± 6.29^{b}	1902 ± 0.22^{a}	1927 ± 4.45^{a}	0.0001***
	Basic	1423 ± 34.18^{b}	1344 ± 0.90^{c}	2321 ± 9.69^{a}	2324 ± 4.55^{a}	0.0001***
	P-value	1	0.165	0.122	0.976	

^{a,b,c,d}: the means with the different letters in the same row are significantly different (P<0.05). Day 0 = 0 day of fermentation of the palm kernel meal; Days 2; 4 and 6 = correspond to the different numbers of days of fermentation of the palm meal both in the humic acid and in the limestone solution. DM = Dry matter; P: Probability. NS= Non-significant (P>0.05); *=P<0.05; **= P<0.01; ***= P<0.001.

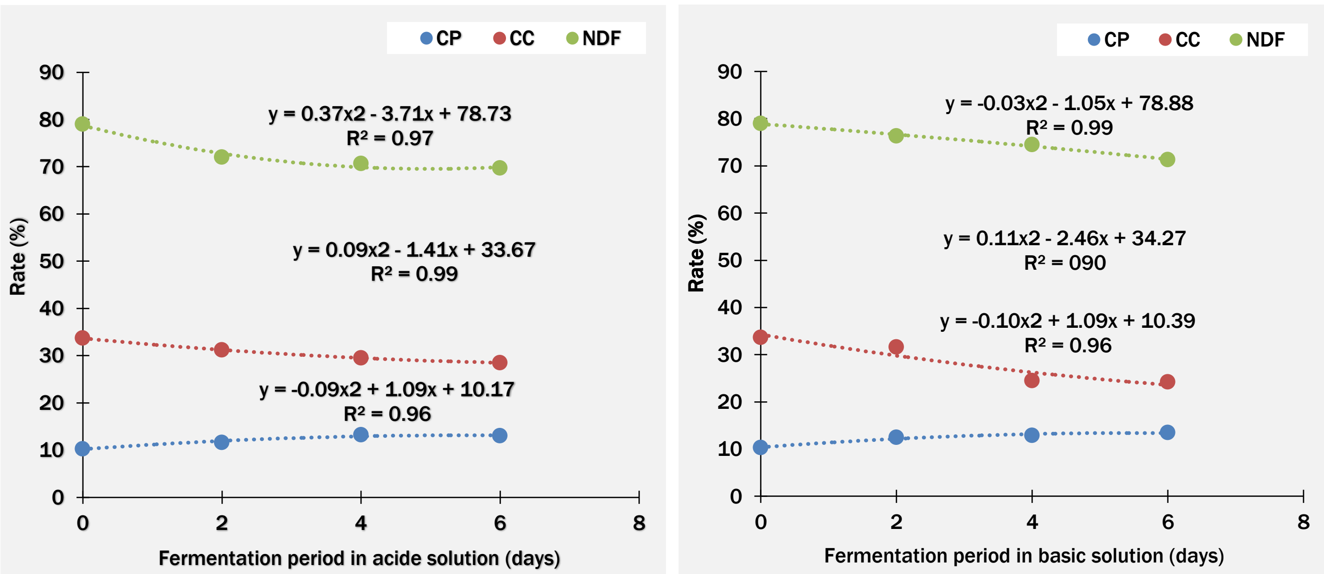
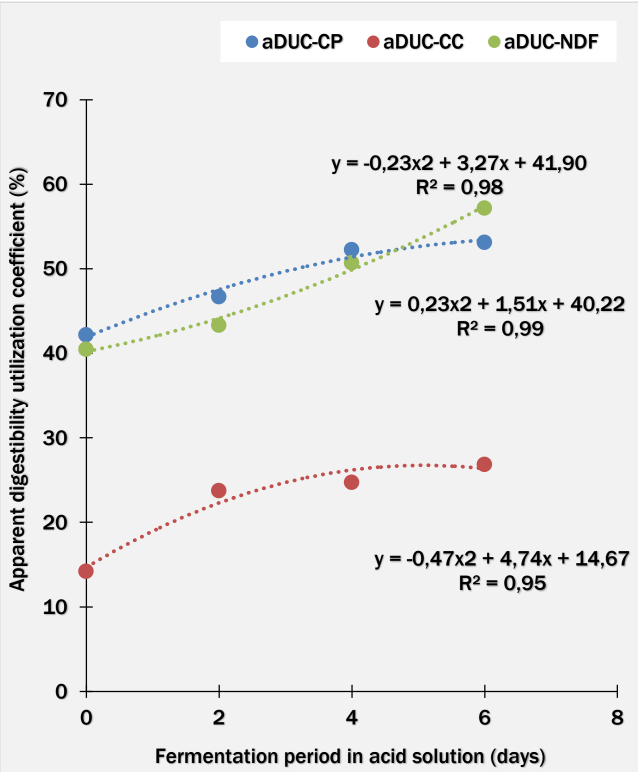


Figure 1 - Regression of crude protein (CP), crude cellulose (CC) and Neutral Detergent Fiber (NDF) with respect to the fermentation period of palm kernel cake.

Table 3 - Effects of palm kernel meal fermentation mode and period on feed digestibility of broiler chickens

Type of fermentation		Control		Fermentation period (days)			P-value
		R0	R0+	2	4	6	
aDUC - Dry matter (%)							
	Acid	63.79 ± 3.40[a]	49.48 ± 3.36[c]	54.60 ± 1.56[bc]	54.45 ± 4.64[bc]	56.93 ± 2.25[b]	0.004**
	Basic	63.79 ± 3.40[a]	49.48 ± 3.36[b]	50.83 ± 3.65[b]	52.53 ± 4.55[b]	54.94 ± 2.58[b]	0.004**
	P-value	1.000	1.000	0.131	0.153	0.248	
aDUC -Organic matter (%)							
	Acid	72.70 ± 3.04[a]	62.23 ± 2.89[c]	65.54 ± 1.15[ab]	66.35 ± 0.20[ab]	66.86 ± 2.25[b]	0.002**
	Basic	72.70 ± 3.04[a]	62.23 ± 2.89[c]	65.49 ± 0.69[bc]	65.18 ± 3.50[bc]	67.93 ± 1.39[b]	0.006**
	P-value	1.000	1.000	0.272	0.370	0.276	
aDUC - Protein (%)							
	Acid	47.73 ± 6.20	42.19 ± 4.34	47.69 ± 9.48	52.24 ± 3.57	53.12 ± 5.76	0.279[NS]
	Basic	47.73 ± 6.20	42.19 ± 4.34	44.70 ± 7.10	48.49 ± 3.58	48.43 ± 5.04	0.556[NS]
	P-value	1.000	1.000	0.230	0.922	0.558	
aDUC -NDF (%)							
	Acid	59.35 ± 9.47	40.491 ± 5.69	43.32 ± 17.05	50.69 ± 9.49	57.15 ± 1.65	0.242[NS]
	Basic	59.35 ± 9.47	40.491 ± 5.69	43.44 ± 15.65	51.05 ± 7.58	53.00 ± 3.15	0.457[NS]
	P-value	1.000	1.000	0.244	0.496	0.689	
aDUC -Cellulose (%)							
	Acid	15.94 ± 1.14[c]	14.19 ± 0.91[c]	23.74 ± 1.67[b]	24.16 ± 2.36[ab]	26.83 ± 3.22[a]	0.007**
	Basic	15.94 ± 1.14[c]	14.19 ± 0.1[c]	21.34 ± 4.39[b]	23.80 ± 2.31[b]	28.75 ± 0.95[a]	0.0001***
	P-value	1.000	1.000	0.690	0.196	0.482	

[a, b, c, d]: the means with the different letters in the same row are significantly different ($P<0.05$). R0 = treatment without palm kernel meal; R0+ = treatment with unfermented palm kernel meal; 2 = Rations with meal fermented for two days with the humic acid and limestone solution; 4 = Rations with meal fermented for four days with the humic acid and limestone solution; 6 = Rations with meal fermented for six days with the acid and limestone solution; aDUC: apparent digestive utilization coefficients; NDF: Neutral detergent fiber. NS= non-significant ($P>0.05$); *=$P<0.05$; **= $P<0.01$; ***= $P<0.001$



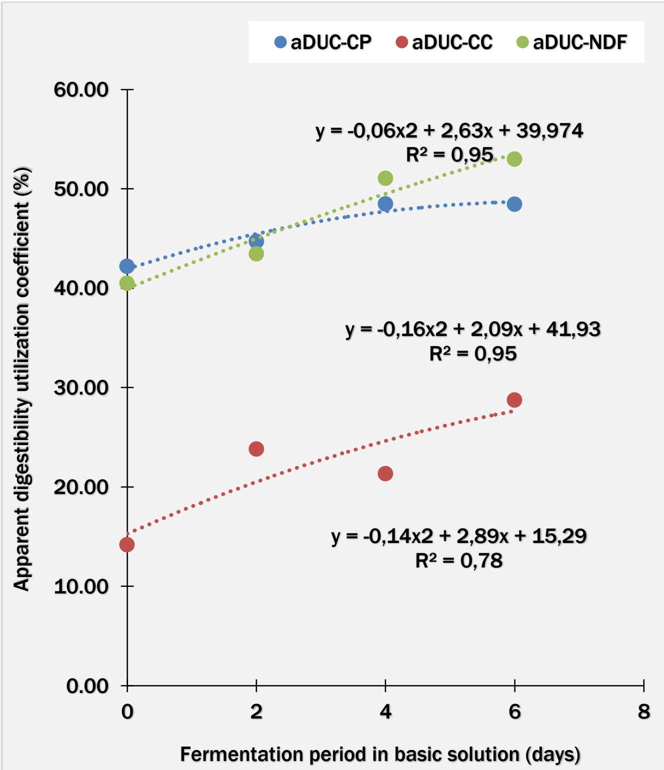


Figure 2 - Regressions curves of the apparent digestive coefficients of crude protein (aDUC –CP), crude cellulose (aDUC-CC) and Neutral Detergent Fiber (aDUC-NDF) with respect to the fermentation period of palm kernel meal.

Table 4 - Effects of palm kernel meal fermentation mode and duration on broiler growth performances

Fermentation mode		Control		Fermentation time (days)			P-value
		R0	R0+	2	4	6	
Feed intake (g)							
	Acid	4530.62 ± 237.41	4340.25 ± 316.91	4479.87 ± 240.59	4523.37 ± 151.47	4544.62 ± 413.74	0.374^{NS}
	Basic	4530.62 ± 237.41	4340.25 ± 316.91	4671.25 ± 129.96	4432.25 ± 264.38	4562.37 ± 377.26	0.327^{NS}
	P-value	1^{NS}	1^{NS}	0.901^{NS}	0.681^{NS}	0.417^{NS}	
Live weight (g)							
	Acid	2705.62 ± 275.07	2474.87 ± 125.73	2599.50 ± 208.04	2658.25 ± 228.88	2698.25 ± 45.76	0.413^{NS}
	Basic	2705.62 ± 275.07	2474.87 ± 125.73	2662.62 ± 55.26	2658.37 ± 171.12	2686.12 ± 176.83	0.487^{NS}
	P-value	1.000^{NS}	1.000^{NS}	0.807^{NS}	0.060^{NS}	0.133^{NS}	
Weight gain (g)							
	Acid	1947.31 ± 275.08	1716.56 ± 125.73	1841.19 ± 208.04	1899.94 ± 228.88	1939.94 ± 45,76	0.137^{NS}
	Basic	1947.31 ± 275.08	1716.56 ± 125.73	1904.31 ± 55.26	1900.06 ± 171.12	1927.81 ± 176,83	0.487^{NS}
	P-value	1.000^{NS}	1.000^{NS}	0.404^{NS}	0.060^{NS}	0.133^{NS}	
Feed conversion ratio							
	Acid	2.32 ± 1.967	2.52 ± 0.20	2.43 ± 0.06	2.38 ± 0.03	2.34 ± 0.03	0.254^{NS}
	Basic	2.32 ± 1.967	2.52 ± 0.20	2.45 ± 0.06	2.33 ± 0.09	2.37 ± 0.,24	0.269^{NS}
	P-value	1.000^{NS}	1.000^{NS}	0.745^{NS}	0.101^{NS}	0.978^{NS}	

R0: treatment without palm kernel meal; R0+ = treatment with unfermented palm kernel meal; 2 = Rations with meal fermented for two days with the humic acid solution and with the limestone solution; 4 = Rations with meal fermented for four days with the humic acid solution and with the limestone solution; 6 = Rations with meal fermented for six days with the acid solution and with the limestone solution. P: probability. NS= non-significant (P>0.05); NS= non significant.

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DISCUSSION

Regardless of the fermentation mode, the chemical composition of palm kernel meal improved with increasing fermentation period in humic acid and limestone solution. Thus, the lowest cellulose content and the highest lipid, organic matter, crude protein and energy contents were recorded after 6 days of fermentation. This result is in agreement with those of Mirnawati et al. (2017, 2019) who reported that the fermentation of palm kernel meal with humic acid + *Sclerotium rolfsii* and *Bacillus subtilis* respectively improved the chemical composition of palm kernel meal.

The cellulose content of palm kernel meal decreased significantly with increasing fermentation period. In fact, the longer the fermentation period, the lower the crude cellulose content. This could be justified by the fact that, the longer the fermentation period, the more fungi grow and the more cellulase is produced to break down cellulose (Sudharmono et al., 2016). Similarly, the longer the fermentation period, the more cellulase produce which converts cellulose into glucose, and thus explains the lower cellulose content of this meal. This result is similar to those of Mirnawati et al. (2017, 2019), who reported an improvement in the chemical composition of palm kernel meal with increasing fermentation period in organic solutions.

The longest fermentation period (6 days) resulted in significantly higher protein content than that obtained with the other fermentation period. This result corroborates the findings of Mirnawati et al. (2019), who reported that a longer fermentation period of palm kernel meal an increase protein content. This can be explained by the fact that the longer the fermentation period, the greater the number of microbes that proliferate. Thus, the increase in microbial growth contributes to the increase in protein content due to microbial proteins. The increase in crude protein content could also be due to the presence of enzymes produced by the microbes, as the greater the number of microbes in the fermentation process, the more enzymes, which are proteins, will be produced (Mirnawati et al., 2010; 2012, 2013).

Whatever the fermentation mode, the energy level of palm kernel meal increased significantly with the fermentation period. This can be due to the decrease in crude cellulose content, converted into glucose by cellulolytic microbes, on one hand, and the increase in fat content on the other. Through this process, fermentation transforms feed ingredients containing proteins, fats and carbohydrates that are difficult to digest for the benefit of chickens (Mirnawati et al., 2019). Irrespective of the fermentation period, NDF digestibility was not significantly affected by the fermentation mode. This could be explained by limestone's ability to soften cellulose walls, as well as the enzymatic activity of the micro-organisms produced thanks to humic acid. This result is in line with the findings of José da Silva (2020), as an anti-acid and alkalizing agent, limestone reduces flatulence, thus improving digestibility. In the same line, Mirnawati et al. (2010) reported that humic acid (HA) provides energy that favors the development of cellulolytic micro-organisms, leading to improved digestibility.

Irrespective of fermentation mode, crude cellulose digestibility increased significantly with the fermentation period. The high crude cellulose digestibility of the ration containing the meal fermented for 6 days could be related to the low crude cellulose content of the ration. This is in line with the work of Mirnawati et al. (2017, 2019), who reported that crude fiber digestibility of ration depends on the crude fiber content of the ingredients that are in the feed. The higher the crude fiber content, the lower the digestibility of the feed due to the poultry's limitations in digesting cellulose. Digestion is also influenced by several other factors, such as crude fiber composition and the activity of micro-organisms (Maynard et al., 2005). According to Walugembe et al. (2014), fermentation promotes the multiplication of catabolic micro-organisms, which break down complex components into simpler ones, making them easier to digest.

Irrespective of the fermentation mode, feed intake, weight gain, live weight and feed conversion ratio of broilers fed diets containing palm kernel meal fermented for 2, 4 and 6 days were comparable to those fed the control ration without palm kernel meal. This result can be attributed to fermentation, which improved the digestibility of all feed components, enabling the chickens to take advantage of the nutrients contained in the palm kernel meal. Fermentation is said to have improved the palatability of the feed through the quality of its aroma and taste, which was appreciated by broilers. This is in accordance with the findings of Sukaryana et al. (2010) and Mirnawati et al. (2018) who reported that fermentation, improves the aroma and taste of fermented feed, which thereby increases boiler's feed intake.

CONCLUSION

Crude protein, lipid and energy content of palm kernel meal increase with its fermentation period in humic acid and limestone solution, while crude cellulose and NDF content decrease. Improving the nutritional value of this resource through fermentation enables broilers to have growth performances comparable to those produced with a ration containing only soybean meal as the main source of plant-derived protein. Fermenting this meal for a period longer than 6 days and increasing its incorporation level in the ration will be necessary to better assess its effects on broiler growth.

DECLARATIONS

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Data availability
The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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The authors have no competing interests (none).

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