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Challenzyme Supplementation of High Expeller Copra Meal in Corn-animal Protein Diets for Broilers: Growth Performance, Nutrient Digestibility and Carcass Traits

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ABSTRACT

A five-week experiment was conducted to investigate the effects of Challenzyme supplementation of expeller copra meal (ECM) fed in corn-animal protein-based diets on growth performance, nutrient digestibility, carcass and gut measurements of broilers. A total of 168, 9 days old Cobb 500 broilers were assigned to 8 diets consisting of 2 controls (with and without enzyme) and 6 other diets consisting 150, 300 and 450 g/kg ECM levels (with and without enzyme), were fed in three replicates of 6 birds each in a completely randomized design. Results showed significant interactions effects on growth parameters and fat digestibility. Feed intake and weight gain were reduced on 300 and 450 g/kg ECM diets ($P<0.05$). Fat digestibility was improved on control and 300 g/kg ECM diets with enzyme ($P<0.05$). Carcass measurements were not affected by dietary treatments ($P>0.05$). In the main effects, feed intake and weight gain were reduced and feed conversion ratio increased with increasing level of ECM above 150 g/kg ($P<0.05$). Enzyme supplementation improved crude fibre and fat digestibility of broilers ($P<0.05$). In conclusion, 300 g/kg dietary ECM with enzyme inclusion has no detrimental effects on growth of finishing broilers. More research into enzyme source and concentration above 300 g/kg ECM is recommended.

Keywords: Alternative protein sources, Broiler performance, Diet composition, Exogenous enzyme, Nutrient digestibility

INTRODUCTION

Exorbitant feed cost has directed research efforts into alternative feed resources for poultry feeding. Traditional protein sources such as soybean meal is expensive in the South Pacific region. Copra meal is readily available in the region and could be utilised to reduce feed cost. The crude protein content of ECM ranges from 150-250 g/kg (Devi and Diarra, 2017; Diarra *et al.,* 2018; Devi and Diarra, 2019). The lower essential amino acid profile, especially lysine and methionine (Sundu *et al.,* 2009; Devi and Diarra, 2017; Devi and Diarra, 2019) and high non-starch polysaccharides (NSP) contents (420-610 g/kg) (Knudsen, 1997; Devi and Diarra, 2017; Saittagaroon *et al.,* 1983 cited in Sundu *et al.,* 2012) are the major limitations to the efficient utilisation of ECM in poultry diets. Dietary recommendations range from 50-300 g/kg (Sundu *et al.,* 2006; Bastos *et al.,* 2007; Diarra *et al.,* 2014; Diarra *et al.,* 2015; Devi and Diarra, 2017). Several technologies including amino acid and enzyme supplementation (Sundu *et al.,* 2004; 2009; Diarra *et al.,* 2014), choice of dietary ingredients (Devi and Diarra, 2017) and feed processing (Sundu *et al.,* 2009) can improve the utilisation of ECM in poultry diets. Recently, Devi and Diarra (2017) observed that broilers could utilise 150 g/kg ECM fed in diets based on corn-animal proteins (fish meal and meat and bone meal) better than plant protein sources. This study investigated the effect of enzyme supplementation of ECM in corn-animal protein based diets. We hypothesized that:

i) Higher levels of ECM can be fed in corn-animal protein diets without adverse effects on broiler growth; and
ii) Enzyme supplementation will improve the utilisation of the diets by broilers.

MATERIALS AND METHODS

The study, consisting of 2 experiments (1 and 2) was carried out at Ratish Poultry farm, Nausori, Fiji where ECM is readily available from Fiji Co-operative Dairy Company Limited and Copra Millers Fiji Limited.

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The research committee of the University of the South Pacific approved the experimental protocol.

The protein sources were analysed for proximate composition and amino acid profiles (Tables 1 and 2) and used in the formulation of the experimental diets. Eight broiler starter and finisher diets containing 230 and 200 g/kg crude protein, respectively were formulated (Table 3). The diets consisted of a control without ECM and three other diets containing 150, 300 and 450 g/kg ECM with and without enzyme. All diets were based on fish meal and meat and bone meal as main protein sources. Challenzyme 1309A, a complex enzyme from Beijing Challenge Bio-Technology Company Limited, with the following enzyme activities; β-glucanase 800 U/g, xylanase 15000 U/g, β-mannanase 100 U/g, α-galactosidase 100 U/g, Protease 8000 U/g, amylase 500 U/g, pectinase 500 U/g and cellulase 300 U/g was used for the study. All diets were based on fish and meat and bone meals as protein sources.

A total of 168 day-old Cobb 500 broiler chicks purchased from Pacific feeds limited, Suva, Fiji were warm brooded on deep litter with wood shavings as litter material for a period of 7 days on commercial starter feed. On day 8, the birds were weighed individually (232.9 ± 3.58 g; 1.54 CV) and allotted to 28 cages (65.5 cmõ 50 cm × 35.5 cm) containing 5 birds each and allowed to adapt for two days. The experimental diets were fed to each birds in 4 pens in a factorial arrangement (4 ECM x 2 enzyme) laid in a completely randomized design. The experiment lasted for 30 days (10 -40 d). Feed and water were provided *ad libitum* throughout the duration of the experiment. The birds were exposed to 22 hours lighting during the experimental period.

Data on growth parameters (feed intake, weight gain, and feed conversion ratio) were monitored throughout the experiment. Feed intake was calculated by difference between the quantities fed and left-over. Body weight gain was obtained by difference between the initial and final weights. Feed conversion ratio (FCR) was calculated as the ratio of feed consumed by weight gained.

At d 33, one bird having the closest weight to the group mean was selected from each cage (4 birds per treatment) and placed in individual cages for digestibility studies. After 3 days of adaptation to the cages, weighed quantities of feed were fed and excreta samples collected from each bird for a period of 4 days. Excreta samples were oven-dried at 60º C for 48 hours, ground and analyzed for proximate composition and apparent total tract digestibility was calculated as:

$$\% \text{ Nutrient Digestibility} = \frac{\text{Nutrient intake} - \text{Nutrient in faeces}}{\text{Nutrient intake}} \times 100$$

At the end of the experiment (day 40), all birds

Table 1. Proximate composition, NDF and ADF (g/kg), and metabolisable energy (MJ/kg) content of the experimental protein sources

Constituents	Protein sources		
	FM	MBM	ECM
ME (MJ/kg)	11.31	13.44	10.88
Dry matter	725	879	887
Crude protein	531	481	184
Ether extract	106	253	120
Ash	117	144	49
Crude fibre	5	21	189
NDF	222	250	441
ADF	26	82	271
NSP	-	-	419

ME: metabolisable energy (calculated); FM: fish meal; MBM: meat and bone meal; ECM: expeller copra meal, NSP: non-starch polysaccharides; NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre were fasted overnight but allowed access to water. The birds were weighed early in the morning and euthanized by decapitation for carcass and organ measurements. Slaughtered birds were scalded in hot water (about 55°C) for about one minute, plucked manually and eviscerated. The eviscerated chickens were weighed and dressing out percentage was calculated as:

$$\%\ \text{dressing} = \frac{\text{carcass weight}}{\text{live weight}} \times 100$$

Gut segments (crop, proventriculus, gizzard, small intestine and caeca) and annex glands (liver, pancreas) were also removed and weighed using an electronic scale sensitive to 0.1 gram and expressed as percentage of the live weight.

Data collected were subjected to ANOVA (Steel and Torrie, 1980) of the GLM in SPSS (SPSS for Windows, version 22.0; IBM Corp., Armonk, NY, USA). Individual birds were the experimental units for weight change, carcass and organ measurements and nutrient digestibility whereas cages were the experimental units for feed intake. Treatment means were compared using the Least Significant Difference (LSD) and significant differences were reported at 5% level of probability.

RESULTS AND DISCUSSION

Data pertaining to growth performance of the broilers are presented in Table 4. During the starter phase (10-21days), there were no effects on feed intake and FCR ($P>0.05$). Weight gain was improved on control and 150 ECM diet compared to 300 g/kg without and 450 g/kg with enzyme ($P<0.05$). In the main effects, increasing ECM level significantly ($P<0.05$) reduced feed intake and weight gain but had no effect on FCR ($P>0.05$). Enzyme supplementation had no effect on the growth parameters observed ($P>0.05$). No mortality was recorded during the course of the experiment.

In the starter phase, feed intake and FCR were not affected by the interaction of copra and enzyme

Table 2. Amino acid composition of the experimental protein sources (mg/100 mg DM)

Amino acid	Protein sources (mg/100 mg)		
	FM	MBM	ECM
Aspartic acid	4.58	3.61	1.48
Threonine	2.16	1.67	0.56
Serine	2.13	1.90	0.79
Glutamic acid	6.68	5.63	3.12
Proline	2.84	3.20	0.62
Glycine	4.61	5.21	0.81
Alanine	3.44	3.16	0.80
Valine	2.27	1.95	0.89
Isoleucine	1.85	1.45	0.56
Leucine	3.46	2.87	1.10
Tyrosine	1.50	1.18	0.47
Phenylalanine	1.87	1.56	0.74
Histidine	1.50	1.26	0.39
Lysine	3.84	2.75	0.64
Arginine	3.29	3.12	2.35
Cysteine	0.36	0.25	0.28
Methionine	1.41	0.90	0.31
Tryptophan	0.46	0.30	0.15

FM: fish meal; MBM: meat and bone meal; ECM: expeller copra meal; DM: Dry matter probably due to the similarity in nutrient content of the experimental diets on one hand and the lower energy requirements of young broilers on the other. Poultry consume feed to meet its requirements of energy (NRC, 1994; Smith, 2001; Classen *et al.,* 2016). The improved weight gain on 150 g/kg ECM diet is contrary to the findings of Sundu *et al.* (2004) who reported reduced gain in 4-14 weeks old broilers fed 100 g/kg dietary ECM. In the study cited above broilers were fed ECM in corn-soybean diets against corn-animal protein diets in the current study. The superiority of animal over plant protein sources is well documented (Vieira and Lima. 2005; Bhuiyan *et al.,* 2012a; Hossain *et al.,* 2012; 2013; Devi and Diarra, 2017). Devi and Diarra (2017) reported improved weight gain in broilers fed ECM in corn-animal protein as compared to corn-soybean diets and attributed this to increased nutrient availability from animal protein sources in the former diet. Possible beneficial effects of ECM fibre on the gut of young birds could also be a reason for improved weight gain on the ECM diets. Early feeding of ECM mannan-oligosaccharides improved intestinal enterocyte length and villus surface area resulting in better nutrient utilisation and weight gain in broilers (Noy *et al.,* 2001).

In the finisher phase (22-40 days) feed intake and weight gain were significantly affected by ECM and enzyme supplementation (P<0.05). Feed intake and weight gain were reduced on 450 g/kg diets and 300 g/kg diet without enzyme (P<0.05). Like in the starter phase, there was no interaction effect on FCR during the finisher phase (P>0.05). The main effects showed decreased feed intake, weight gain and poorer FCR with increasing ECM level (P<0.05). Enzyme addition had no effects on feed intake, weight gain and FCR (P>0.05). The finisher phase showed reduced FI and WG in the interaction effects above 300 g/kg ECM diets. Significant interaction effects (P<0.05) was observed during the phase. Birds fed 450 and 300 g/kg ECM diet without enzyme consumed less feed and gained less weight (P<0.05). In the main effects, feed intake and weight gain were reduced and FCR increased with increasing level of ECM above 150 g/kg (P<0.05). Enzyme addition did not affect the growth parameters (P>0.05).

Sundu *et al.* (2006) observed similar trend in broilers fed corn-soybean diets at 0, 100, 300 and 500 g/kg ECM supplemented with Hemicell®, Allzyme SSF® and Gamanase® and their combination. Several authors have attributed lower intake of ECM-based diets by poultry to the NSP (Sundu *et al.,* 2009; Diarra *et al.,* 2014; Devi and Diarra, 2017; Diarra *et al.,* 2018). The reason for poor performance above 300 g/kg in the current study was not clear but reduced feed intake due to longer digesta transit time in the gastro-intestinal tract (GIT) could be speculated. Several authors (Svihus *et al.,* 2002; Svihus, 2011; Mateos *et al.,* 2012) have reported longer digesta transit leading to poor performance of poultry fed ECM-based diets. Enzyme supplementation could not improve weight gain on 300 g/kg ECM. It is possible that the level of enzyme (0.3 g/kg) used in the diet was not sufficient to hydrolyse the ECM fibre. The effect of enzyme source and concentration on the utilisation of ECM is well documented (Sundu *et al.,* 2009; Diarra *et al.,* 2015).

From the results of nutrient digestibility of the broilers (Table 6), it is evident that there was no significant (P>0.05) interaction effect on dry matter, crude protein and crude fibre digestibility, but there was a significant interaction effect on fat digestibility (P<0.05). Addition of ECM depressed fat digestibility, but enzyme supplementation improved fat digestibility of the 300 g/kg ECM similar to the control diets (P<0.05). In the main effects, the digestibility of all nutrients reduced with increasing level of ECM (P<0.05). Enzyme supplementation did not affect dry matter and crude protein digestibility (P>0.05) but improved crude fibre and ether extract digestibility (P<0.05).

Dietary NSP concentration, class and age of birds are reported to affect nutrient digestibility in poultry (Choct and Annison, 1990; Carré *et al.,* 1995). Carré *et al.* (1995) found lower digestibility of corn-soybean diets in adult broilers compared to cockerels. Dietary NSP binds bile salts, cholesterol, lipids (Vahouny *et al.,* 1980:1981, cited in Choct, 1997) and reduces efficient absorption of nutrients in the intestine wall (Johnson and Gee, 1981, cited in Choct, 1997). NSPs also increase

Table 3. Ingredient composition and calculated nutrient content (g/kg, as fed basis) of the experimental diets

Ingredients (g/kg)	Starter diets								Finisher diets							
	ECM with no enzyme				ECM with enzyme				ECM with no enzyme				ECM with enzyme			
	0	**150**	**300**	**450**	**0**	**150**	**300**	**450**	**0**	**150**	**300**	**450**	**0**	**150**	**300**	**450**
Corn	550.1	453	355.8	258.8	550.1	452.6	355.5	258.5	550.3	468.8	389.8	310.4	550.3	464.8	389.6	310.2
Wheat bran	110	90.6	71.2	51.8	110	90.5	71.1	51.9	145.1	104.4	64.9	25.2	145.1	104.3	64.8	25.1
Fishmeal	94.2	82.6	71.1	59.6	94.2	82.6	71.2	59.7	89.4	78.8	67.9	57.1	89.4	78.8	67.9	57.1
MBM	188.4	165.3	142.4	119.3	188.4	165.3	142.4	119.3	158.7	137.5	115.9	94.3	158.7	137.6	115.9	94.3
Copra meal	0	150	300	450	0	150	300	450	0	150	300	450	0	150	300	450
Coral sand	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Limestone	20	20	20	20	20	20	20	20	10	10	10	10	10	10	10	10
*Premix	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Lysine	1	2	2.5	3	1	2	2.5	3	0.8	1	1.5	2	0.8	1	1.5	2
Methionine	0.8	1	1.5	2	0.8	1	1.5	2	0.3	0.5	0.6	0.6	0.3	0.5	0.6	0.6
Enzyme	-	-	-	-	0.3	0.3	0.3	0.3	-	-	-	-	0.3	0.3	0.3	0.3
Salt	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Calculated nutrient content																
Crude protein	230	230	230	230	230	230	230	230	200	200	200	200	200	200	200	200
ME (MJ/kg)	12.39	12.41	12.44	12.46	12.39	12.41	12.44	12.46	12.19	12.34	12.51	12.68	12.19	12.28	12.50	12.67
Lysine	12	13	12	12	12	13	12	12	11	11	10	10	11	11	10	10
Methionine	5	5	6	6	5	5	6	6	5	5	4	4	5	5	4	4

MBM, meat and bone meal; ECM: expeller copra meal; ME: metabolisable energy; *Premix (Vitamin and mineral) Bio-mix supplied/kg diet, vitamin A: 10 000 IU, vitamin D_3: 2000 IU, vitamin E: 23 mg, niacin: 27.5 mg, vitamin B_1: 1.8 mg, B_2: 5 mg, B_6: 3 mg, B_{12}: 0.015 mg, vitamin K: 3.2 mg, pantothenic acid:7.7mg, biotin:0.06 mg, folic acid: 0.75 mg, choline chloride: 300 mg, cobalt: 0.2 mg, copper: 3 mg. iodine: 1mg, iron: 20 mg, manganese: 40 mg, selenium: 0.2 mg, zinc: 30 mg, anti-oxidant: 1.25 mg.

Table 4. Growth performance of broiler starter fed different ECM (g/kg) levels with animal protein sources and Challenzyme supplementation

Treatment		Feed intake (kg)			Weight gain (kg)			FCR (feed: gain)		
Copra	Enzyme	10-21 d	22-40 d	10-40 d	10-21 d	22-40 d	10-40 d	10-21 d	22-40 d	10-40 d
0	No	4.49	15.16^{ab}	19.66^{a}	1.34^{a}	5.78^{ab}	7.12^{a}	3.35	2.63	2.77
	Yes	4.50	16.06^{a}	20.15^{a}	1.37^{a}	6.28^{a}	7.57^{a}	3.28	2.57	2.67
150	No	4.46	14.47^{bc}	18.93^{a}	1.33^{a}	5.43^{b}	6.76^{ab}	3.35	2.67	2.81
	Yes	4.34	14.91^{b}	19.25^{a}	1.28^{ab}	5.40^{b}	6.68^{ab}	3.39	2.76	2.88
300	No	3.96	12.90^{c}	16.86^{b}	1.15^{c}	4.40^{c}	5.55^{c}	3.44	2.94	3.05
	Yes	4.29	14.72^{bc}	19.01^{a}	1.27^{b}	5.41^{b}	6.69^{ab}	3.37	2.72	2.84
450	No	4.02	13.53^{c}	17.54^{ab}	1.24^{b}	4.66^{c}	5.90^{c}	3.24	2.91	2.98
	Yes	3.84	12.74^{c}	16.57^{b}	1.10^{c}	4.38^{c}	5.48^{c}	3.48	2.91	3.03
SEM		0.146	0.421	0.509	0.018	0.215	0.208	0.091	0.071	0.056
Main effects										
Copra										
0		4.50^{a}	15.61^{a}	19.90^{a}	1.36^{a}	6.03^{a}	7.35^{a}	3.31	2.60^{b}	2.72^{b}
150		4.40^{ab}	14.69^{b}	19.09^{a}	1.31^{b}	5.41^{b}	6.72^{b}	3.37	2.72^{ab}	2.84^{ab}
300		4.12^{bc}	13.81^{c}	17.93^{b}	1.21^{c}	4.90^{c}	6.12^{c}	3.40	2.83^{a}	2.94^{a}
450		3.93^{c}	13.13^{c}	17.06^{b}	1.17^{d}	4.52^{c}	5.69^{c}	3.36	2.91^{a}	3.00^{a}
Enzyme										
No		4.23	14.02	18.25	1.27	5.07	6.33	3.34	2.79	2.90
Yes		4.24	14.61	18.74	1.26	5.37	6.61	3.38	2.74	2.85
Probabilities										
Copra		0.003	0.000	0.000	0.000	0.000	0.000	0.809	0.001	0.000
Enzyme		0.928	0.059	0.179	0.404	0.060	0.077	0.560	0.325	0.284
Copra*Enzyme		0.324	0.037	0.043	0.000	0.028	0.006	0.293	0.185	0.061

ECM: expeller copra meal; FCR: Feed Conversion Ratio; SEM: Standard Error of Mean; ^{a,b,c}Values within the column with different superscripts differ significantly ($P<0.05$)

digesta viscosity in the gut which decreases diffusion rate of digestive enzymes and substrates and disturbs their interaction at mucosal surface level (Ikegami *et al.,* 1990, cited in Choct, 1997). Prolonged feeding time of soluble NSP results in adaptive changes such as enlargement of organs, increased digestive secretion and nutrient absorption (Choct, 1997). Increased level of dietary insoluble fibre reduces digesta retention time (Kirwan *et al.,* 1974, cited in Choct, 1997) which may affect nutrient digestibility. The improved fat digestibility on 300 g/kg ECM with enzyme diet was not understood but probably due to differences between plant and animal fats. The reduced fat digestibility on 450 g/kg ECM diets may be attributed to the inability of the broiler to digest ECM fat at this level of inclusion. The effect of fat source on nutrient digestibility is well documented. Allahyari-Bake and Jahanian (2016) found improved ether extract digestibility of birds fed soy oil and soy free fatty acid in corn-soybean as well as in corn-soybean-wheat meal based diets. Huo *et al.* (2018) fed 50 g/kg lard, sesame oil and flaxseed oil in corn-soybean meal based diets to broilers and found improved crude fat digestibility in sesame and flaxseed oil compared to lard. The authors suggested that fat source could possibly affect nutrient digestibility. Higher ECM levels increases the residual oil content and this may have contributed to improved fat digestibility in finishing broilers in the current study.

In the main effects, the digestibility of most nutrients was reduced with increasing ECM level further confirming the adverse effect of ECM fibre on nutrient digestibility. Sundu *et al.* (2006) observed reduced dry matter (DM) digestibility on 100 g/kg ECM in 4-14-day old Ross broilers fed corn-soybean diets but supplementation with Hemicell®, Allzyme SSF® and Gamanase® or their combination improved DM digestibility by the birds. The authors attributed poor performance to quality of ECM. The improved crude fibre and ether extract digestibility of the enzyme supplemented ECM up to 300 g/kg may explain the enhanced growth performance observed on this diet.

The results of carcass studies and gut measurement of broilers are presented in Table 5. There were no significant interaction or main effects of ECM and enzyme supplementation on any of the carcass parameters studied (P>0.05). This may suggest that all diets met the requirements of the birds for muscle development. Devi and Diarra (2017) found no effect of 150 g/kg dietary ECM in corn-animal protein diets on thigh and drumstick yields. Contrary to the findings of this study, however, Diarra *et al.* (2014) observed reduced dressing percentage and breast weights in finishing broilers fed cassava-ECM diets compared to the control commercial feed. As earlier mentioned, differences in feed processing and composition of basal diet are all possible factors affecting the utilisation of ECM by poultry.

Gut measurements results of the broilers showed no interaction effects on the weights of liver, crop, proventriculus, gizzard and small intestine (P>0.05). Pancreas weight was reduced on negative control (without enzyme) compared to 300 g/kg without enzyme but did not differ among positive control, 150 with enzyme and 450 g/kg ECM diets (P<0.05). Heavier caeca weight was observed on 150 g/kg without enzyme, 300 g/kg with enzyme and 450 g/kg without enzyme ECM diets (P<0.05).

In the main effects, there was a significant effect of ECM on the weight of all gut segments (P<0.05). The liver was lighter on 450 g/kg ECM (P<0.05). Birds fed 150 g/kg ECM, had lighter crop compared to control but crop weight did not differ among the ECM diets (P<0.05). Proventriculus weight was increased on the ECM diets (P<0.05). A lower (P<0.05) gizzard weight was recorded on control compared to ECM-based diets. Birds fed 450 g/kg ECM had the heaviest small intestines (P<0.05). Enzyme addition reduced (P<0.05) caeca weight but did not affect the rest of the segments (P>0.05). There were no interaction or main effects of ECM and enzyme addition on the relative weights of carcass and cuts (breast, thigh and drumstick).

Heavier pancreas on the 300 g/kg ECM with enzyme was not clear but could be due to longer digesta retention which might have increased pancreatic secretion to hydrolyse fibre. Diarra *et al.* (2014) reported heavier pancreas in broilers fed cassava-ECM

Table 5. Relative weights of carcass and gut segments (% live weight) of the broilers fed different ECM (g/kg) levels with animal protein sources and Challenzyme supplementation

Treatment: Copra	Treatment: Enzyme	Dressing	Breast	Thigh	Drum-stick	Liver	Pancreas	Crop	Proven-triculus	Gizzard	Small Intestine	Caeca
0	No	72.92	21.89	10.65	1.80	1.69^{c}	0.45	0.28	1.59	2.67	0.22^{bc}	9.73
	Yes	74.37	23.66	11.80	2.03	2.06^{ab}	0.51	0.24	1.58	2.97	0.12^{c}	11.07
150	No	73.29	20.52	11.34	1.82	1.80^{bc}	0.23	0.39	2.05	2.74	0.46^{a}	10.86
	Yes	71.62	20.45	10.66	1.62	2.13^{ab}	0.22	0.45	1.90	2.67	0.28^{b}	10.91
300	No	69.18	19.13	10.65	1.74	2.44^{a}	0.36	0.28	2.00	2.86	0.28^{b}	10.38
	Yes	73.89	22.19	11.29	1.88	1.93^{bc}	0.22	0.45	1.95	2.68	0.45^{a}	10.19
450	No	71.78	20.50	11.46	1.54	2.20^{ab}	0.34	0.34	1.97	3.60	0.41^{a}	10.48
	Yes	72.02	19.14	10.87	1.59	2.23^{ab}	0.41	0.35	2.06	3.05	0.28^{b}	11.80
SEM		1.338	1.145	0.433	0.104	0.104	0.078	0.047	0.144	0.151	0.036	0.548
Main effects												
Copra												
0		73.64	22.78	11.23	1.92^{a}	1.87^{b}	0.48^{a}	0.26^{b}	1.58^{b}	2.82^{b}	0.17^{b}	10.40
150		72.45	20.49	11.00	1.72^{a}	1.97^{b}	0.23^{b}	0.42^{a}	1.97^{a}	2.70^{b}	0.37^{a}	10.88
300		71.53	20.66	10.97	1.81^{a}	2.18^{a}	0.29^{ab}	0.36^{a}	1.97^{a}	2.77^{b}	0.36^{a}	10.29
450		71.90	19.82	11.16	1.57^{b}	2.21^{a}	0.38^{ab}	0.34^{ab}	2.01^{a}	3.33^{a}	0.34^{a}	11.14
Enzyme												
No		71.79	20.51	11.03	1.72	2.03	0.34	0.32	1.90	2.97	0.34^{a}	10.36
Yes		72.97	21.36	11.16	1.78	2.09	0.34	0.37	1.87	2.84	0.28^{b}	10.99
Probabilities												
Copra		0.433	0.084	0.921	0.019	0.007	0.022	0.017	0.020	0.001	0.000	0.375
Enzyme		0.223	0.304	0.672	0.452	0.456	0.955	0.156	0.789	0.251	0.027	0.118
Copra*Enzyme		0.140	0.250	0.114	0.230	0.001	0.560	0.179	0.869	0.070	0.000	0.369

ECM: expeller copra meal; SEM: Standard Error of Mean; [a,b,c]Values within the column with different superscripts differ significantly (P=0.05);

diets compared to commercial feed and attributed this to increased pancreatic activity for hydrolysis of the fibrous diet. Devi and Diarra (2017) also observed similar trend of pancreas weight on corn-soybean diets containing 150 g/kg ECM. The pattern of caeca weight was not understood but probable increased fibre fermentation on the 150 g/kg ECM without enzyme and low feed intake or slower digesta transit above this level of ECM inclusion are speculated. Shortening of digesta transit time as a result of feeding high levels of insoluble NSP (Choct, 1997) and increase transit time on high levels of soluble NSP (Choct *et al.,* 1996) have been reported. Our findings are contrary to those of Diarra *et al.* (2014) who reported no effect of cassava-ECM diets on caeca weight of finishing broilers. Factors including source of ECM, inclusion level and diet composition may affect gut weight of birds.

The reduced liver weight on 450 g/kg ECM diet was attributed to the reduced intake of this diet in the main effects. The 150 g/kg ECM diet might have transited faster along the gastro-intestinal tract resulting in lighter crop on this diet. Possible increase in digestive secretion in the proventriculus and increased gizzard activity with increasing ECM may explain the weight pattern of these gut segments. Diarra *et al.* (2014) found heavier gizzard on cassava-ECM diets of finishing broilers compared to commercial diet and attributed this to digesta retention time on the fibrous

Table 6. Nutrient digestibility (%) of the broiler chickens fed different levels of ECM (g/kg) with animal protein sources and Challenzyme supplementation

Treatment		Dry matter	Crude protein	Crude fibre	Ether extract
Copra	Enzyme				
0	No	88.94	63.27	61.68	78.89^{a}
	Yes	91.37	69.87	74.80	81.34^{a}
150	No	83.51	64.12	49.78	71.74^{b}
	Yes	84.41	64.59	65.91	66.02^{c}
300	No	84.99	46.18	48.38	66.11^{c}
	Yes	83.63	54.48	55.37	80.82^{a}
450	No	83.99	37.64	35.50	61.54^{c}
	Yes	83.61	42.69	48.38	63.97^{c}
SEM		1.264	4.450	3.884	1.529
Main effects					
Copra					
0		90.15^{a}	66.57^{a}	68.24^{a}	80.12^{a}
150		83.96^{b}	64.35^{a}	57.84^{b}	68.88^{c}
300		84.31^{b}	50.33^{b}	51.87^{b}	73.47^{b}
450		83.80^{b}	40.17^{c}	41.94^{c}	62.76^{d}
Enzyme					
No		85.36	52.80	48.84^{b}	69.57^{b}
Yes		85.75	57.91	61.11^{a}	73.04^{a}
Probabilities					
Copra		0.000	0.000	0.000	0.000
Enzyme		0.662	0.118	0.000	0.004
Copra*Enzyme		0.484	0.835	0.697	0.000

ECM: expeller copra meal; SEM: Standard Error of Mean; ^{a,b,c}Values within the column with different superscripts differ significantly (P=0.05) diets. Amerah *et al.* (2009) also reported increased gizzard volume with increasing dietary structural components. Copra meal fibre is reported to increase secretion of digestive enzymes and gizzard development (Svihus, 2011; Mateos *et al.,* 2012; Kheravii *et al.,* 2018). The weight of small intestine increased on 450 g/kg ECM with enzyme probably due to longer digesta retention and an attempt by this segment to increase enzymatic hydrolysis. These findings agree with the report of Diarra *et al.* (2014) who observed heavier small intestine weights in birds fed diets containing 500 g/kg ECM with Allzyme SSF. The authors attributed heavier weights to increased digesta retention time on the test diet. In another study, Sundu (2011) attributed heavier small intestine weight of birds fed an ECM-based compared to corn-soy diets to larger body, beak and feed particle size.

CONCLUSIONS

Based on the experimental results, it is concluded that feeding up to 300 g/kg ECM fed with animal protein sources with enzyme supplementation has no adverse effects on broiler growth and nutrient digestibility. These findings would reduce cost of broiler production in coconut producing regions. More research is recommended into ECM source, diet composition, enzyme product and concentration.

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