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Original Article

Haematology, Carcass and Fatty Acid Composition of Finishing Broilers Fed Enzyme Supplemented Expeller Copra Meal in Corn-Animal Protein Diets

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ABSTRACT

This study analyzes the effect of different levels of expeller copra meal (ECM) in animal protein-based diets with enzyme on the haematology, carcass and fatty acid composition of broilers. One hundred and sixty 20 days old Cobb broilers were assigned 8 different diets, 2 of them being controls and 6 others containing ECM at 150, 300 and 450 g/kg, with or without enzymes. Four replicate cages of 5 birds each were fed the diets in a completely randomized design. Higher white blood cell (WBC) counts were obtained in chickens fed the control and 150 g/kg ECM with enzyme (p<0.05) diets. Meat saturated fatty acids (SFA) content increased on the 150 g/kg diet and later decreased above 300 g/kg without enzyme (p<0.05). Monounsaturated fatty acid (MUFA) content was reduced with the inclusion of increasing ECM levels (p<0.05). No interaction effect on polyunsaturated fatty acids (PUFA) was found. Main effects observed were MUFA and PUFA decrease with the inclusion of ECM in the diet (p<0.05). Saturated fatty acid (SFA) content was found to increase on the 150 g ECM/kg diet and later to reduce with increasing ECM levels (p<0.05). Enzyme supplementation reduced SFA and MUFA content (p<0.05) but had no effect on PUFA (p>0.05). In conclusion, inclusion of ECM up to 300 g/kg in corn-animal protein diets has no adverse effects on most broiler haematological variables, but meat fatty acid composition may be altered. More research into basal diet composition, enzyme source and concentration is recommended.

INTRODUCTION

Poultry products are the main components of Fijians' diets, but high feed cost is a major factor affecting domestic production. Soybean meal, a conventional protein source, is in limited supply and expensive in the country. This calls for research into readily available alternative protein resources for poultry feeding. Expeller extracted copra meal (ECM), a moderate protein source, is readily available in the country. Copra meal contains 150-250 g/kg crude protein (Devi & Diarra, 2017; Diarra *et al.*, 2018; Devi & Diarra, 2019). The high non-starch polysaccharides (NSP) content (420-610 g/kg) (Knudsen, 1997; Sundu *et al.,* 2012; Devi & Diarra, 2017) and low essential amino acid profile, especially lysine and methionine (Sundu *et al.,* 2009; Devi & Diarra, 2017; Devi & Diarra, 2019), are major factors affecting the utilisation of ECM in poultry feeding. Dietary recommendations of ECM are variable, ranging from 50-300 g/kg (Sundu *et al.,* 2006; Diarra *et al.,* 2014; Devi & Diarra, 2017) depending on the species, age and class of poultry. There have been studies on nutrient utilisation in broilers fed high fibre by-products using enzyme supplementation and probiotics (Sayehban *et al*., 2015; Sayehban *et al*., 2016; Seidavi *et al*., 2017; Woyengo

et al., 2018; Head *et al.,* 2019). Several techniques improve poultry ECM utilisation, such as amino acid and enzyme supplementation (Sundu *et al.,* 2009; Diarra *et al.,* 2014), diet composition (Devi & Diarra, 2017), and processing methods (Sundu *et al*., 2009). The residual fat in ECM (35 to 120 g/kg; Ravindran & Blair, 1992; Sundu *et al.,* 2009; Devi & Diarra, 2019) is a valuable energy source in the diet. However, ECM fat is mainly in the form of saturated fatty acids (NRC, 1994; DeMandal & Mandal., 2011; Ghosh *et al.,* 2014; Boateng *et al.,* 2016). The effect of dietary fat sources on the fatty acid composition of poultry products is well documented (Carmona *et al.,* 2006; Smink *et al.,* 2010; Kanakri *et al.,* 2018). Cherian (2011) fed fish and sunflower oils at 35 g/kg in corn-soybean diets to broiler breeders and found increased long chain omega 3 and omega 6 fatty acids in the meat. Supplementation with enzymes (Raza *et al*., 2009; Anuradha & Roy, 2015), amino acids (Kumar *et al*., 2016) and probiotics (FAO, 2016) is reported to improve poultry utilisation of high fibre diets. Raza et al. (2009) observed improved fibre digestibility in sunflower based diets supplemented with NIBGE enzyme. Devi and Diarra (2017) found that broilers can better utilize ECM when it is fed with animal proteins (fishmeal and meat with bone meal) than in soybean diets. Although diet composition is known to affect the fatty acid composition of poultry products (Cherian, 2016), the effect of feeding ECM in corn-animal protein-based diets on poultry meat fatty acid composition is not documented. This study investigated the effect of varying levels of ECM in corn-animal protein based diets with enzyme on haematology, carcass traits and fatty acid composition of broiler meat. The hypotheses were that feeding high ECM levels will not affect:

I. Some haematological parameters;
II. Carcass measurements; and
III. Fatty acid composition of broiler meat

MATERIALS AND METHODS

Experimental site

The study consisted of two experiments and was conducted at Ratish Poultry farm, Nausori, Fiji. The rainfall and air temperature in the study area during the experiment ranged from 765 to 1,093 mm and 25.8 to 27.4°C, respectively (Fiji Meteorological Services, 2017). Expeller Copra Meal is readily available from Fiji Cooperative Dairy Company Limited located near the experimental farm. The research committee of the University of the South Pacific approved the experimental protocol.

Experimental diets

The proximate composition and amino acid profiles of protein sources were analyzed (Tables 1 and 2). Eight broiler finisher diets (200 g/kg CP) were formulated, consisting of two control diets without ECM and six diets based on 150, 300 and 450 g ECM /kg with and without enzymes (Table 3). The enzyme used for the study was Challenzyme 1309A, from Beijing Challenge Bio-Technology Company Limited, with 8 active components (amylase 500 U/g, α-galactosidase 100 U/g, ß-glucanase 800 U/g, ß-mannanase 100 U/g, Cellulase 300 U/g, Protease 8000 U/g, Pectinase 500 U/g and Xylanase 15000 U/g).

Table 1 – Proximate composition, NDF and ADF (g/kg) and metabolisable energy (MJ/kg) of 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

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

Amino acid	Protein sources (mg/100mg)		
	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.

Table 3 – Ingredient composition and calculated analysis (g/kg, as fed basis) of finisher diets.

Ingredients (g/kg)	Finisher diets							
	ECM with no enzyme.				ECM with enzyme.			
	0	150	300	450	0	150	300	450
Corn	550.3	468.8	389.8	310.4	550.3	464.8	389.6	310.2
Wheat bran	145.9	108.9	68.8	26.9	145.7	109.6	68.9	26.7
Fishmeal	89.4	78.8	67.9	57.1	89.4	78.8	67.9	57.1
Meat & bone	158.8	137.5	116.9	98.5	158.7	140.5	116.7	98.6
Copra meal	0	150	300	450	0	150	300	450
Coral sand	30	30	30	30	30	30	30	30
Limestone	19	19	19	19	19	19	19	19
*Premix	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Lysine	0.8	1	1.5	2	0.8	1	1.5	2
Methionine	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
Salt	3	3	3	3	3	3	3	3
Calculated analysis								
Crude protein	200	200	200	200	200	200	200	200
ME (MJ/kg)	12.19	12.34	12.51	12.68	12.19	12.28	12.50	12.67
Lysine	11	11	10	10	11	11	10	10
Methionine	5	5	4	4	5	5	4	4

ECM: expeller copra meal; ME: metabolisable energy

*Premix (Vitamin and mineral) Bio-mix supplied/kg diet, vitamin A: 10 000 IU, vitamin D3: 2000 IU, vitamin E: 23mg, niacin: 27.5mg, vitamin B1: 1.8 mg, B2: 5mg, B6: 3mg, B12: 0.015mg, vitamin K: 3.2mg, pantothenic acid: 7.7mg, biotin: 0.06mg, folic acid: 0.75mg, choline chloride: 300mg, cobalt: 0.2mg, copper: 3mg. iodine: 1mg, iron: 20mg, manganese: 40mg, selenium: 0.2mg, zinc: 30mg, anti-oxidant: 1.25mg.

Experimental broilers and management

One hundred sixty-eight day-old Cobb 500 male broilers were purchased from Pacific Feeds Limited and brooded together for 7 days on commercial starter feed. They were placed over deep litter, feed and water were provided *ad-libitum* and continuous lighting was provided during the brooding phase. On the 8th day, one hundred and sixty birds were individually weighed (232.9 ± 3.58 g) and allocated to 32 cages (65.5 cm x 50 cm x 35.5 cm) containing 5 birds each. Each experimental diet was fed to birds in 4 of the replicate cages. The poultry shed had East-West orientation and was open sided with mesh having dimensions (10 m x 5 m x 3 m). After 2 days of adaptation to the cages, the birds were fed the experimental diets for 30 days (10–40 d) using factorial arrangement (4 ECM x 2 enzymes). Diets and clean water were provided *ad-libitum* throughout the experimental period. The lighting programme consisted of 22 h light and 2 h dark. This was achieved by providing artificial lighting from the evening till night and switching it off 2 hours before daybreak.

Data collection

Blood collection and analysis

On day 35, 1 ml of blood was collected from the brachial vein of one bird per replicate using 23-gauge needles with 2 ml sterile syringes. The samples were placed in clean, labelled heparinised tubes (BD Vacutainer) containing 1mg of Ethylene Diamine Tetra Acetic Acid (EDTA) powder as anti-coagulant. Collected blood samples were thoroughly mixed with the anti-coagulant and stored at a temperature of 4 °C for determination of packed cell volume (PCV), haemoglobin (Hb) concentration, red blood cell (RBC) and white blood cell (WBC) counts following standard procedures at the Veterinary Pathology Laboratory, Nausori, Fiji. An automated haematology analyser, Exigo H400 system (Boule Medical ISO 13485 AB Domnarvsgatan 4 SE-163 53 Spanga, Sweden) was used to analyse WBC and RBC concentrations (cells/µl). Blood films were stained using Wright-Giemsa's staining method and total red and white blood cells were determined using an hemocytometer (Asian Scientific Instruments, ISO 9001: 2008, Hydrabad, India) with Natt & Herrick's (1952) solution as diluting fluid (Campbell, 1994). The differential leukocyte and lymphocyte count smears were prepared, stained using Leishman technique and counted by separation under an optical microscope (Thrall & Weiser, 2002). A micro haematocrit procedure (Thrall & Weiser, 2002) by centrifuging capillary tube samples at 2500 rpm for 5 mins was used to determine packed cell volume (PCV). The cyanmethemoglobin technique (Higgins & Doumas, 2008) was used for determination of haemoglobin concentration.

Carcass measurements

On the 40th day, one bird per replicate was fasted overnight with water supply *ad libitum*. Early next morning, birds were euthanized by decapitation, scalded in water (at about 55 °C) for one minute, manually plucked and eviscerated. The eviscerated carcass was weighed using an electronic scale sensitive to 0.1 g and its value was expressed in relation to live weight. Dressing percentage was calculated as follows:

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

Carcass cuts (breast, thigh and drumstick) were also weighed and expressed as relative to live bird weights.

Fatty acid composition of meat

The breast meat samples were taken from the carcass measurements for total fats and fatty acid composition analysis. 100g fresh breast meat samples were weighed, packed in labelled zip lock bags and taken to the laboratory of the Institute of Applied Sciences, University of the South Pacific, Laucala Campus.

Skinless fresh meat samples were freeze-dried, ground and stored at -20 °C until further analysis. Total fat was determined according to the AOAC (2012, ID 922.06) modified method. Total lipid determination was done gravimetrically using an analytical scale (Marte®, sensitive to 0.001 g). The fatty acid profile was determined using a Hewlett Packard 6890® gas chromatograph (Sukhija & Palmquist, 1988). The carrier gas used was Helium at a 3.0 ml/min flow rate. The injection port and detector temperatures were set respectively at 200 °C and 250 °C. Oven temperature was set to 150 °C for 3 min and increased by 1.5 °C every 3 min until it reached 190 °C. It was then increased at a rate of 1 °C/min up to a final temperature of 220 °C. The retention times and peak area percentages were calculated using a Hewlett Packard computing integrator. Fatty acids were identified by comparing sample retention times with standard retention times (36 saturated, monounsaturated and polyunsaturated fatty acid standards, Sigma and Polyscience, U.S.A.®). Quantification was carried out by normalization and transformation of the area percentage to mg/100 g of edible portion, using Holland (1994) lipid conversion factor. The fatty acid composition of breast meat was calculated as:

Concentration (mg/g) = peak area of a given fatty acid × concentration of internal standard (mg/ml) / peak area of internal standard / sample weight (g).

Statistical analysis

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 gain, carcass and organ measurements and nutrient digestibility, whereas cages were the experimental units for feed intake. Treatment means comparison using the Least Significant Difference (LSD) and significant differences were reported at 5% level of probability.

RESULTS

Haematological parameters

Hematological study results (Table 4) showed no effects of the treatment on PCV, Hemoglobin and RBC (p>0.05), but the WBC count was affected (p<0.05). WBC value decreased in birds fed the 150 g/kg diet when compared to the control (p<0.05), but this was averted with enzyme addition (p>0.05). A lower WBC count was recorded in birds fed 300 g/kg diets with enzyme and 450 g/kg diets with and without enzyme when compared to other diets (p<0.05). Higher WBC counts were recorded on control and 150 g ECM/kg diets with enzyme when compared to the other ECM diets (p<0.05). Main effects observed were that ECM level or enzyme supplementation did not affect observed hematological values (p>0.05).

Carcass traits

The results of broilers' carcass studies are presented in Table 5. There were no significant interactions or main effects of ECM and enzyme supplementation on any of the carcass parameters studied (p>0.05).

Fatty acid composition

Results of fatty acid composition of broiler breast meat presented in Table 6 showed significant interaction effects on saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) (p<0.05). The concentration of SFA decreased on the 300 g ECM/kg with enzyme and 450 g/kg diets. A lower meat MUFA content was observed on the 450 g/kg with enzyme diet, but PUFA composition was unaffected (p>0.05). Main effects observed were that ECM level had significant effects on broiler meat fatty acid composition (p<0.05). The highest SFA value was recorded on the 150 g/kg diet and the lowest on the 450 g ECM/kg diet (p<0.05). Mono unsaturated fatty acid (MUFA) and PUFA content was higher on the control (p<0.05) and reduced with increasing copra meal levels (p<0.05). Enzyme addition significantly

Table 4 – Some haematological parameters of broiler chickens fed different ECM levels (g/kg) with animal protein sources and enzyme supplementation.

Treatment		Feed intake	PCV	WBC	Hemoglobin	RBC
Copra	Enzyme	(kg)	(%)	(x10^9/L)	(g/dL)	(x10^{12}/L)
0	No	19.66^a	37.75	69.05^a	13.63	2.31
	Yes	20.15^a	43.75	66.17^a	14.50	2.48
150	No	18.93^a	33.25	53.23^b	14.33	2.29
	Yes	19.25^a	39.25	64.30^a	13.33	2.12
300	No	16.86^b	36.50	44.30^b	14.03	2.29
	Yes	19.01^a	40.25	27.43^c	14.63	2.45
450	No	17.54^{ab}	40.75	35.35^c	13.73	2.17
	Yes	16.57^b	40.75	30.02^c	14.73	2.28
SEM		0.509	2.941	2.983	0.815	0.159
Main effects						
Copra						
0		19.90^a	40.75	67.61	14.06	2.39
150		19.09^a	36.25	58.76	13.83	2.21
300		17.93^b	38.38	35.86	14.33	2.37
450		17.06^b	40.75	17.68	14.23	2.22
Enzyme						
No		18.25	37.06	50.48	13.93	2.26
Yes		18.74	41.00	39.47	14.29	2.33
Probabilities						
Copra		0.000	0.374	0.151	0.933	0.542
Enzyme		0.179	0.070	0.505	0.528	0.551
Copra*Enzyme		0.043	0.710	0.014	0.592	0.680

PCV: Packed Cell Volume; WBC: White Blood Cells; RBC: Red Blood Cells; SEM: Standard Error of Mean. a, b, c: values within the column with different superscripts differ significantly (p=0.05).

Table 5 – Relative weights of carcass and commercial cuts (% live weight) of broilers fed different ECM levels (g/kg) with animal protein sources and enzyme supplementation.

Treatment		Dressing	Breast	Thigh	Drumstick
Copra	Enzyme				
0	No	72.92	21.89	10.65	9.73
	Yes	74.37	23.66	11.80	11.07
150	No	73.29	20.52	11.34	10.86
	Yes	71.62	20.45	10.66	10.91
300	No	69.18	19.13	10.65	10.38
	Yes	73.89	22.19	11.29	10.19
450	No	71.78	20.50	11.46	10.48
	Yes	72.02	19.14	10.87	11.80
SEM		1.338	1.145	0.433	0.548
Main effects					
Copra					
0		73.64	22.78	11.23	10.40
150		72.45	20.49	11.00	10.88
300		71.53	20.66	10.97	10.29
450		71.90	19.82	11.16	11.14
Enzyme					
No		71.79	20.51	11.03	10.36
Yes		72.97	21.36	11.16	10.99
Probabilities					
Copra		0.433	0.084	0.921	0.375
Enzyme		0.223	0.304	0.672	0.118
Copra*Enzyme		0.140	0.250	0.114	0.369

SEM: Standard Error of Mean.

Table 6 – Breast meat fatty acid composition (g/100g) of broilers fed different ECM levels (g/kg) with animal protein sources and enzyme supplementation.

Treatment		SFA	MUFA	PUFA
Copra	Enzyme			
0	No	0.69^{bc}	0.70^a	0.24
	Yes	0.64^c	0.71^a	0.32
150	No	1.19^a	0.58^b	0.23
	Yes	1.00^a	0.52^b	0.15
300	No	0.91^{ab}	0.42^c	0.12
	Yes	0.34^d	0.39^c	0.12
450	No	0.55^{cd}	0.40^c	0.12
	Yes	0.13^d	0.18^d	0.09
SEM		0.084	0.032	0.034
Main effects				
Copra				
0		0.66^b	0.71^a	0.28^a
150		1.09^a	0.55^b	0.19^b
300		0.63^b	0.40^c	0.12^{bc}
450		0.34^c	0.29^d	0.11^c
Enzyme				
No		0.83^a	0.52^a	0.18
Yes		0.53^b	0.45^b	0.17
Probabilities				
Copra		0.000	0.000	0.000
Enzyme		0.000	0.004	0.776
Copra*Enzyme		0.021	0.008	0.135

SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; SEM: Standard Error of Mean; a, b, c: values within the column with different superscripts differ significantly (p=0.05).

reduced SFA and MUFA compositions (p<0.05) but did not affect breast meat PUFA composition (p>0.05).

DISCUSSION

Haematological parameters

Blood profiles is a good assessment of nutritional and health status. Improved feed intake and protein digestibility on the 150 g/kg ECM diet could be reasons for higher WBC count in the present study. The beneficial effect of mannan fibre on gut health is well reported (Sundu *et al.,* 2012; Putri *et al.,* 2017). Putri *et al.* (2017) observed higher leukocyte counts in broilers fed a 0.35g ECM mannan oligosaccharides per kg diet when compared to control and antibiotic supplemented diets. Similarly, Konca *et al.* (2009) reported no effect of commercial mannan oligosaccharides on turkeys' blood profile. Fernandez *et al*. (2002) found higher leukocyte counts and improved immune responses in broilers fed mannan containing palm kernel cake diets. The short chain fatty acids (SCFA) produced from caecal fermentation of complex fibres improve gut health by suppressing harmful bacteria and improving bird immune responses. Decreasing levels of WBC counts were observed with increasing levels of ECM. The lower WBC count observed in this experiment despite the higher feed intake on the 300g/kg ECM diet with enzyme could not be explained. The activities of several enzymes in Challenzyme 1309A may also affect WBC counts.

Carcass traits

There were no interactions or main effects of ECM and enzyme addition on relative weights of carcass and cuts (breast, thigh and drumstick). This may suggest that all diets met bird requirements for muscle development. Devi & Diarra (2017) found no effects 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 when compared to control commercial feed. As mentioned earlier, differences in feed processing and basal diet composition are all possible factors affecting poultry ECM utilisation.

Fatty acid composition

The lower SFA in the interaction effects on the 450 g ECM/kg diet despite the higher SFA in ECM (Ghosh *et al.*, 2014) may be due to lower intake of this diet. The effect of dietary fat on fatty acid composition of poultry products is well documented. Cherian (2011) fed broiler breeders fish and sunflower oils at 35 g/kg in corn-soybean diets and found increased long chain omega 3 and omega 6 fatty acids in the meat. The author attributed the pattern of breast muscle fatty acid composition to the diet's fatty acid profile, confirming that poultry has a limited ability to transform dietary fat. There are reports of fatty acids manipulation in meat and eggs using dietary fat, alteration in production practices, antioxidants including vitamin E and ginseng (Hargis & Elswyk, 1993; Wood & Enser, 1997; Yan *et al.,* 2011; Cherian, 2016; Head *et al.,* 2019). Wood & Enser (1997) observed quick poultry meat response to dietary concentrations of linoleic, linolenic and total PUFA. Yan *et al.* (2011) found that ginseng root meal inclusion in laying hen diets reduced SFA and increased PUFA in bird egg yolk and attributed this to the PUFA and lower SFA in ginseng root meal. Panaite *et al.* (2019) recommended 50 g dried tomato waste with flaxseed /kg corn-soybean diets in laying hens for maximum n-3 (PUFA) fatty acids in eggs. In another study, Thacker & Widyaratne (2012) recommended 150 g/kg camelina meal for total n-3 and n-6 (PUFA) deposition in broiler meat. Contrary to our findings, Farias *et al.* (2019) observed that up to 250g stored ECM /kg in corn-soybean diets did not alter fatty acid composition in quails. Similarly, Kim *et al.* (2001) found no effect of ECM on fatty acid composition of finishing pigs at 40 g/kg in corn-soybean based diets. The source and intake of dietary fat and the class, age and species of poultry may all affect the fatty acid composition of poultry products. Lower SFA despite higher intake on the 300 g/kg diet with enzyme was not explained and needs to be investigated.

CONCLUSION

In conclusion, inclusion of ECM up to 300 g/kg in corn-animal protein diets without enzyme has no adverse effects on most broilers' hematological variables. Enzyme supplementation maintains meat fatty acid quality in term of PUFA, but MUFA decreases with the dietary ECM level regardless of enzyme addition. Future research into basal diet compositions, enzyme sources and concentrations that reduce production cost and maintain a healthy fatty acid profile is recommended.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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