Impact of commercial feed dilution with copra meal or cassava leaf meal and enzyme supplementation on broiler performance

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ABSTRACT A preliminary study investigated the impact of commercial feed dilution with copra meal (**CM**) or cassava leaf meal (**CLM**) and enzyme supplementation on broiler performance. Commercial feed alone (control) or diluted with CM and CLM at a concentration of 100 and 200 g/kg in the starter and finisher diets, respectively, was fed without and with Challenzyme 300A at a concentration of 300 g/tonne in 2 × 2 factorial arrangements with a control. Two hundred, 7-day-old male, Cobb 500 broiler chicks were randomly assigned to 5 diets containing 4 replicates of 10 birds each. There were no interaction or main effects ($P > 0.05$) on feed intake during either the starter or finisher phase. In the starter phase, feed-to-gain ratio (**F:G**) increased ($P < 0.05$) in the group fed with CM without enzyme. Enzyme supplementation restored F:G similar to the control. Diet dilution with CM or CLM had no effect ($P > 0.05$) on weight gain (**WG**) in the starter phase. Diluting the feed with CM or CLM without enzyme suppressed ($P < 0.05$) WG and F:G in the finisher phase, but enzyme supplementation restored the lost performances. There were no interaction or main effects ($P > 0.05$) on the carcass traits. Enzyme supplementation reduced ($P < 0.05$) feed cost per kilogram of carcass. Heavier ceca were observed in the group fed with dilution diets ($P < 0.05$). Enzyme supplementation reduced cecum weight in the group fed with CM ($P < 0.05$). The heaviest ($P < 0.05$) abdominal fat was recorded in the group fed with enzyme-supplemented CM diet, and the lightest ($P < 0.05$) abdominal fat was recorded in the group fed with CLM with enzyme. In the main effects, lighter ($P < 0.05$) liver, gizzard, and proventriculus were recorded in the group fed with control diet than in the group fed with the CLM diets, but the weight of these segments did not differ ($P > 0.05$) between the control and CM groups and between the fiber sources. The results suggest that dilution of commercial diet with CM or CLM may be a viable option for medium- and small-scale broiler production in the region. There is need for more research in the level of dilution, enzyme source, and concentration.

Key words: broiler, commercial feed, enzyme product, fiber source

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INTRODUCTION

Globally, the greatest increase in poultry meat consumption is taking place in developing countries (Ravindran, 2012; OCED/FAO, 2018). At the same time, domestic production in these countries is still low owing to high feed cost. Feed is the major constraint to increased poultry production in the South Pacific region because conventional ingredients are not readily available. Poultry production in the region is solely dependent on imported commercial feed at high cost. The high feed cost coupled with the booming market for imported poultry meat makes local producers unable to compete. Poultry meat import in Samoa was 87% of all meat imports and 75% of the value of meat imports between 2012 and 2014 (MAF-APHD, 2014, annual report).

Several agro-industrial by-products are included in formulations to reduce cost, but high fiber and low nutrient density, lack of technical skill, and basic feed processing equipment limit their efficient use in poultry feeding in the region. Copra meal (**CM**) is readily available from coconut oil mills in the South Pacific region. With appropriate feed technology, CM could be used to reduce the cost of poultry feed. There are reports on the dilution of commercial feed with low-cost ingredients for broilers (Pandi, 2005; Mael et al., 2020). Dilution of commercial feed with CM up to a concentration of 200 g/kg reduced cost of production without compromising the performance of old broiler breeds grown to 53 d (Pandi, 2005). Recently, Mael et al. (2020) observed

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that dilution of commercial feed with CM at a concentration of 100 g/kg maintained performance of Cobb 500 broilers and reduced cost, but enzyme supplementation allowed dilution up to a concentration of 200 g of CM per kilogram of diet.

Cassava leaf, another readily available agro-industrial by-product in the region, has similar nutritional characteristics to CM (high fiber and low nutrient density). There are reports on the inclusion of cassava leaf meal (**CLM**) in poultry diets (Ravindran, 1991; Eruvbetine et al., 2003; Chauynarong et al., 2009; Oluwafemi and Omaku, 2017), but its use in commercial feed dilution is, to the best of our knowledge, not documented. In addition, supplementation with exogenous enzyme products can improve the utilization of nontraditional feed ingredients and reduce cost and nutrient emission (Chesson, 1993; Berwanger et al., 2017; Rehman et al., 2017; Alagawany et al., 2018; Dayal et al., 2018).

This study compared the potential of CM and CLM to dilute commercial broiler feed with and without enzyme. It was hypothesized that 1) the diluted feed with CM or CLM will produce performance similar to the commercial feed alone and reduce cost and 2) enzyme supplementation will improve the utilization of the diluted feed.

MATERIALS AND METHODS

The study was carried out at the Teaching and Research Farm of the School of Agriculture and Food Technology of the University of the South Pacific. The Animal Ethics Committee of the University approved the experimental protocol.

Experimental Ingredients and Diets

Expeller CM was obtained from Pacific Oil, Samoa (Apia, Samoa). Leaves harvested from 8-month-old sweet cassava cultivar on the crop farm of the School of Agriculture and Food Technology, Apia, Samoa were sun-dried and ground in a hammer mill from Golden Machinery Equipment Co. Limited (Zhengzhou Runxiang, Zhengzhou City, Henan, China) to pass through a 4-mm sieve. The composition of the experimental CM and CLM in selected constituents is presented in Table 1.

Table 1. Composition of the experimental copra meal and cassava leaf meal on dry matter (DM) basis.

Constituents (g/kg)	CM	CLM
Dry matter	907	884
Crude protein	211	229
Ether extract	120	66
Crude fiber	164	181
NDF	441	470
ADF	271	283
Ash	62	97

Abbreviations: ADF, acid detergent fiber; CLM, cassava leaf meal; CM, copra meal; NDF, neutral detergent fiber.

A wheat–soybean–based commercial broiler feed from Pacific Feeds, Suva, Fiji, was used as the control. The commercial feed diluted with CM and CLM without and with enzyme was prepared (Table 2). The commercial feed contained 205 and 190 g/kg of crude protein, 12 and 12.5 MJ/kg of metabolizable energy in the starter and finisher diets, respectively. Both the commercial starter and finisher diets contained 40 g/kg of crude fiber. The dilution level was 100 and 200 g/kg in the starter and finisher diets, respectively. The test diets were supplemented with Challenzyme 1309A from Beijing, China, with 8 enzyme activities (U/g): β-glucanase, 800; xylanase, 15,000; β-mannanase, 100; α-galactosidase, 100; protease, 800; amylase, 500; pectinase, 500; and cellulose, 300 in 300 g/tonne of diet. The diets were also supplemented with HCl-lysine and DL-methionine to compensate for their deficiencies in the test ingredients.

Experimental Birds and Management

Two hundred Cobb 500 male broiler chicks brooded on commercial starter feed for the first 6 d were used for the experiment. On day 7, the chicks were individually weighed (187 ± 15 g) and allotted to 20 open-sided floor pens (2.59 m^2) containing 10 birds each, with wood shaving as litter material. Each diet was fed to 4 replicate pens in a completely randomized design as a factorial arrangement (with a control and 2 fiber sources × 2 enzyme levels). The starter diets were fed as crumbles from 8 to 21 d and the finisher as pellet from 22 to 35 d. The experiment was terminated at day 35 to comply with government advisories following the COVID-19 pandemic. Feed and water were provided ad libitum during the experimental period. The birds received 24 h of light for up to 14 d and 13 h thereafter.

Data Collection

Feed intake (**FI**), weight gain (**WG**), feed-to-gain ratio (**F:G**), carcass and gut measurements, and *Escherichia coli* count formed the response criteria. Feed supplied and leftover feed were weighed per pen, and FI was calculated by difference. The birds were weighed on day 21 and day 35, and WG during the starter and finisher phases was calculated by difference. F:G was derived per pen as feed consumed divided by weight gained.

At 35 d, 2 birds weighing closest to the pen mean were fasted overnight and euthanized by cervical dislocation for carcass measurements. The euthanized chickens were scalded at 50°C for 30 s, plucked manually, and eviscerated. The weights of the eviscerated carcass and economic cuts (breast, drumstick, and thigh) were expressed as percentages of the live weight. Feed cost per kilogram of carcass was determined based on the price of each diet.

Gut segments (proventriculi, gizzards, small intestines, and ceca) were removed and weighed using a portable digital scale (portable scale; Jadever JKH-500

Table 2. Ingredient composition (as-fed basis) and nutrient content of the experimental diets.

	Starter diets			Finisher diets		
Ingredients (g/kg)	Control	Control + CM	Control + CLM	Control	Control + CM	Control + CLM
Commercial feed	1,000	900	900	1,000	800	800
CM	-	100	-	-	200	-
CLM	-		100	-	-	200
HCl Lysine	-	7.3	7	-	1.08	1.3
DL-Methionine	-	0.3	0.2	-	0.3	0.1
Analyzed values						
Crude protein	205	206	207	190	194	198
Crude fiber	40	52	55	40	69	73
Calculated values						
Calcium	8.0	7.9	7.8	7.5	7.3	7.3
Available phosphorus	4.0	3.8	3.9	3.5	3.4	3.4
Lysine	12	12	12	10.4	10.4	10.4
Methionine	5	5	5	4.3	4.3	4.3
ME (MJ/kg)	12	12	11.7	12.5	12.4	11.8
Cost per kilogram (US$)	0.85	0.82	0.78	0.84	0. 78	0.70

Abbreviations: CM, copra meal; CLM, cassava leaf meal; ME, metabolizable energy.

series, Smartfox, Auckland, New Zealand) sensitive at 0.1 g and expressed as percentages of the live weight of the bird. The length of the small intestine was taken, from the duodenum to the ileocecal valve, using a measuring tape and expressed as cm/kg of body weight. The ceca (full) were removed, placed in labeled sterile sample bottles with ice, and sent immediately to the microbiology laboratory for *E. coli* count. Cecal digesta samples (1 g) were mixed with 9 mL of physiological saline water and serially diluted in nutrient broth from initial 10^{-1} to 10^{-9}. About 100 µL of diluted samples was plated on the eosin methylene blue. The samples were incubated on MacConkey agar at 37°C for 24 h (Wang et al., 2017). *E. coli* was counted based on colony morphology and expressed as logarithm of colony-forming unit per gram of the sample.

Chemical Analysis

The test ingredients (CM and CLM) were analyzed as per standard procedures (AOAC, 1995). Dry matter was determined after 24 h in a forced air oven (103°C). Nitrogen content was analyzed using the Kjeldahl method (AOAC, 1995, ID 954.01), and crude protein was calculated as follows: nitrogen × 6.25 (feed factor). Total fat, ash, and fiber content was analyzed as per AOAC (1995, ID 942.05, 920.39, and 962.09 respectively). Acid detergent fiber and neutral detergent fiber were determined as per the methods used by Van Soest et al. (1991).

Statistical Analysis

Data were subjected to analysis of variance for 2 × 2 factorial arrangements plus a control (Steel and Torrie 1980) using the GLM function in SPSS (SPSS for Windows 2013, version 22.0; IBM Corporation, Armonk, NY). The main and interaction effects between treatments were tested. Pen was the experimental unit for FI, WG, and F:G, whereas carcass traits, organ weight, and *E. coli* count were analyzed in individual birds. Treatment means were compared using the least significant difference test, and differences were considered significant at $P < 0.05$.

RESULTS

Growth Performance

The growth performance results of the broilers are presented in Table 3. There were no significant ($P > 0.05$) interaction or main effects on FI and WG during the starter and finisher phase, but F:G was depressed ($P < 0.05$) in the group supplemented with CM without enzyme, which was restored by enzyme supplementation. There was no difference ($P > 0.05$) between the groups fed with control and CLM-based diets during the starter phase. During the finisher phase, FI was not affected ($P > 0.05$) by the interaction or main effects. Diet dilution with either CM or CLM reduced WG and increased F:G ($P < 0.05$), but enzyme supplementation restored WG and F:G comparable with the control.

Carcass Measurements

The results of carcass measurements of the broilers are presented in Table 4. There were no interaction or main effects of the diet on any of the carcass traits ($P > 0.05$). Enzyme supplementation had no effects ($P > 0.05$) on the relative weights of the carcass, breast muscle, thigh, and drumstick but significantly reduced ($P < 0.05$) feed cost per kilogram of carcass.

Organ Measurements and E. coli Count

From the results of organ measurements and *E. coli* count (Table 5), only the weight of ceca and abdominal fat were affected ($P < 0.05$) by the interaction. Heavier ceca were observed in the group fed with dilution diets ($P < 0.05$). Enzyme supplementation of the diet diluted with CM reduced cecum weight similar to the control, but enzyme addition to the CLM diet had no effect ($P > 0.05$) on cecum weight. The heaviest ($P < 0.05$)

Table 3. Growth performance of broilers fed with commercial diet alone or diet diluted with copra meal or cassava leaf meal and enzyme supplementation.

Treatment	Starter phase (8–21 d)			Finisher phase (22–35 d)		
	FI (g/bird)	WG (g/bird)	F:G (g feed:g gain)	FI (g/bird)	WG (g/bird)	F:G (g feed:g gain)
Control	1,051	803	1.31[b]	2,811	1,735[a]	1.62[c]
Control + CM without enzyme	1,037	710	1.46[a]	2,515	1,338[c]	1.88[a]
Control + CM with enzyme	1,032	788	1.31[b]	2,740	1,548[a,b]	1.77[a,b,c]
Control + CLM without enzyme	1,022	730	1.40[a,b]	2,558	1,390[b,c]	1.84[a,b]
Control + CLM with enzyme	1,035	734	1.41[a,b]	2,619	1,578[a]	1.66[b,c]
SEM	31	28	0.042	91.0	62.0	0.065
Main effects						
Diet						
Control	1,051	803	1.31	2,811	1,735	1.62
Control + CM	1,035	749	1.38	2,628	1,443	1.82
Control + CLM	1,028	732	1.40	2,589	1,484	1.74
Enzyme						
Without	1,030	720	1.43	2,537	1,364	1.86
With	1,034	761	1.36	2,680	1,563	1.71
Probabilities						
Diet	0.094	0.000	0.068	0.101	0.000	0.002
Enzyme	0.153	0.152	0.508	0.153	0.000	0.001
Diet × enzyme	0.087	0.091	0.046	0.078	0.032	0.004

[a,b,c]Treatment means with common superscripts do not differ ($P < 0.05$).
Abbreviations: CLM, cassava leaf meal; CM, copra meal; F:G, feed-to-gain ratio; FI, feed intake; WG, weight gain.

abdominal fat was recorded in the group fed with the enzyme-supplemented CM diet, and the lowest ($P < 0.05$) abdominal fat was recorded in the group fed with CLM with enzyme. Abdominal fat weight did not differ ($P > 0.05$) between the control, CM without enzyme, and the CLM-based diets. In the main effects, lighter ($P < 0.05$) liver, gizzard, and proventriculus were recorded in the group fed with the control diet than in the group fed with the CLM diets, but the weight of these segments did not differ ($P > 0.05$) between the control and CM groups and between the fiber sources. There were no interaction or main effects ($P > 0.05$) on intestine weight and *E. coli*. Intestine length was not affected ($P > 0.05$) by the interaction. In the main effects, diet dilution with CLM increased ($P < 0.05$) intestine length.

DISCUSSION

Growth Performance

Reports on commercial diet dilution with low-cost fibrous ingredients for broilers are still scanty. In this study, we observed no interaction or main effects on FI and WG during the starter phase probably owing to smaller digestive capacity of the young broilers. Although not significant, feeding CM without enzyme numerically reduced WG, which resulted in an increased

Table 4. Relative weight of carcass and cuts (percentage) of broilers fed with commercial diet alone or diet diluted with copra meal or cassava leaf meal and enzyme supplementation.

Treatment	Carcass (%, live weight)	Breast muscle (%, live weight)	Thigh (%, live weight)	Drumstick (%, live weight)	US$/kg of carcass
Control	73.67	27.57	12.75	10.58	1.85
Control + CM without enzyme	69.30	26.1	13.37	10.24	2.06
Control + CM with enzyme	72.72	26.48	12.93	11.20	1.92
Control + CLM without enzyme	70.82	25.09	11.82	10.93	2.11
Control + CLM with enzyme	69.79	25.82	12.15	11.06	1.66
SEM	1.273	0.942	0.740	0.520	0.085
Main effects					
Control	73.67	27.57	12.75	10.58	1.85
Control + CM	71.01	26.29	13.15	10.72	1.99
Control + CLM	70.31	25.45	11.99	10.99	1.88
Enzyme					
Without	71.33	25.78	12.54	10.90	2.00[a]
With	71.26	26.50	12.65	10.65	1.79[b]
Probabilities					
Diet	0.073	0.284	0.314	0.658	0.073
Enzyme	0.363	0.854	0.942	0.439	0.003
Diet × enzyme	0.101	0.562	0.607	0.310	0.077

[a,b]Treatment means with common superscripts do not differ ($P < 0.05$)
Abbreviations: CLM, cassava leaf meal; CM, copra meal.

Table 5. Relative weight of gut measurement, intestine length, ceca, and *E. coli* count of broilers fed with commercial diet alone or diluted with copra meal or cassava leaf meal and enzyme supplementation.

Treatment	Liver (%, live weight)	Gizzard (%, live weight)	Proventriculus (%, live weight)	Ceca (%, live weight)	Abdominal (%, live weight) fat	Intestine (%, live weight)	Intestine length (cm/kg weight)	*E. coli* count (log10 cfu/g)
Control	2.64	1.8	0.38	0.50^{c}	$1.11^{b,c}$	3.78	10.46	7.73
Control + CM without enzyme	3.31	2.21	0.40	$0.70^{a,b}$	1.27^{b}	4.0	11.38	7.36
Control + CM with enzyme	3.17	2.03	0.40	$0.66^{b,c}$	1.66^{a}	3.84	11.45	7.56
Control + CLM without enzyme	3.22	2.19	0.41	0.90^{a}	$0.95^{b,c}$	4.64	13.19	7.33
Control + CLM with enzyme	3.27	2.21	0.43	$0.71^{a,b}$	0.80^{c}	5.07	13.4	7.40
SEM	0.242	0.133	0.037	0.059	0.115	0.429	0.648	0.263
Main effects								
Control	2.64^{b}	1.80^{b}	0.38^{b}	0.50	1.11	3.78	10.46^{b}	7.73
Control + CM	$3.24^{a,b}$	$2.12^{a,b}$	$0.40^{a,b}$	0.68	1.47	3.92	11.41^{b}	7.46
Control + CLM	3.70^{a}	2.42^{a}	0.45^{a}	0.81	0.87	4.86	13.29^{a}	7.37
Enzyme								
Without	3.19	2.14	0.40	0.80	1.11	4.03	11.67	7.47
With	3.47	2.23	0.45	0.68	1.23	4.46	12.42	7.48
Probabilities								
Diet	0.014	0.003	0.014	0.007	0.000	0.046	0.000	0.479
Enzyme	0.994	0.584	0.157	0.110	0.306	0.757	0.763	0.612
Diet × enzyme	0.561	0.357	0.215	0.039	0.034	0.503	0.882	0.805

[a,b,c]Treatment means with common superscripts do not differ ($P < 0.05$).
Abbreviations: CLM, cassava leaf meal; CM, copra meal.

F:G on this diet. Enzyme supplementation improved F:G, suggesting that the young broilers were not able to efficiently use this level of CM compared with CLM probably owing to differences in fat content (120 and 66 g/kg, respectively, Table 1). The low ability of young birds to digest dietary fat due to limited secretion of bile salts is documented (Katongole and March, 1980; Diarra, 2018). Katongole and March (1980) reported better utilization of dietary fat in 6-week-old than in 3-week-old birds. The authors attributed this to inefficient recycling of bile salt in younger birds. Diarra (2018) also observed that laying hens used coconut oil–supplemented diets better than broilers and attributed it to age differences. Differences in fiber composition between the experimental CM and CLM could also be a possible reason for the pattern observed. Our results contrast with those of Mael et al. (2020) who found no effect of diluting commercial feed with 100 g of CM per kilogram on F:G in the same broiler breed during the starter phase. These authors started the experiment with 10-day-old broiler chicks compared with 7-day-old chicks in the present study.

During the finisher phase, WG was suppressed in both the groups fed with CM or CLM dilution diets without enzyme, but this was overcome by enzyme supplementation, confirming the activity of the enzyme in improving nutrient availability from the diluted diets. Similar to our results, Mael et al. (2020) also observed reduced WG in finishing Cobb 500 broilers fed with commercial diet diluted with 200 g of CM per kilogram without enzyme and restoration with enzyme supplementation. The authors attributed this to the beneficial effect of enzyme products on the utilization of CM. Enzyme supplementation also improved the utilization of diets containing CLM by growing pullets (Diarra, 2015). A nutrient digestibility study could have provided more insight, but this was not possible owing to difficulties in sending samples overseas during the lockdown.

Carcass Measurements

There were no main or interaction effects on dressing percentage and carcass cuts, suggesting that the birds were able to use CM and CLM at this level of inclusion (100 and 200 g/kg in the starter and finisher diets, respectively). Mael et al. (2020) also reported no effect of diluting commercial broiler feed with CM at the same levels on carcass traits. The reduction in the cost per kilogram of carcass with enzyme addition may be due to improved nutrient availability from the diluted diets. Contrary to this finding, Mael et al. (2020) found no effect of enzyme supplementation on feed cost per kilogram of carcass in their study. These authors used 200 g of Challenzyme per tonne in broilers grown to 42 d against 300 g per tonne in 35-day-old birds in the present study. Enhanced nutrient utilization resulting from increased hydrolysis from higher enzyme concentration may be the major reason for cost reduction in this study.

Gut Weight and E. coli Count

The similarity in organ weights between the control and the diet diluted with CM is in agreement with the finding of Mael et al. (2020) who found no difference in the weight of these organs between the groups fed with control diets and diets diluted with CM in the same broiler breed. The heavier liver, gizzard, proventriculus, and longer intestine in the group fed with diet diluted with CLM may be attributed to possibly longer retention of this diet. Contrary to the results of these authors, however, cecum weight tended to increase in the group fed with diluted diets compared with the group fed with control diet regardless of enzyme supplementation. As mentioned earlier, the age difference between the birds used by these authors and the present study (42 d vs 35 d) may be postulated as a possible reason. The interaction of diets and enzyme tended to reduce cecum weight, further confirming the beneficial effect of additional enzyme on CM- and CLM-based diets. In the present study, enzyme supplementation of the diet diluted with CM increased abdominal fat weight. This trend of fat deposition could not be explained, but it is possible that enzyme addition increased the digestibility of CM fat and energy availability, which might have been deposited as fat in the group fed with this diet. The experimental CM contained more fat than CLM (Table 1). In addition, the fatty acid of CM is mainly in saturated form (Devi et al., 2019) compared with polyunsaturated fatty acids in CLM (Khor and Tan, 1981). Saturated fats have higher digestibility than unsaturated fats (Scheeder et al., 2003). Possible improvement in fat digestibility, following enzyme supplementation of the CM-diluted diet, may also explain the higher fat deposition in birds fed with this diet. Several factors including ration composition and enzyme source and concentration may influence the deposition of abdominal fat in poultry. Although Alaeldein (2012) found no effects of multienzyme supplementation to the corn–soy–based diets on abdominal fat weight in broilers, Garcia et al. (1997) reported heavier abdominal fat in broilers fed with barley–wheat–based diets supplemented with β-glucanase and xylanase. There was no dietary effect on *E. coli* count. Dietary fiber acts mainly on pathogenic bacteria by lowering gut pH through production of short-chain fatty acids (Khan and Iqbal, 2016; Jha et al., 2019). Fiber type and FI influence the extent of fermentation and short-chain fatty acid production (Jha et al., 2019). The experimental CM and CLM were similar in fiber composition. It is possible that at this level of dilution, the fiber content of the diets did not provide enough substrate for meaningful bacterial fermentation in the ceca.

It is concluded that diluting commercial feed with CM or CLM at a concentration of 100 and 200 g/kg in the starter and finisher diets, respectively, and supplementation with enzyme products has no deleterious effects on the growth and carcass traits of broiler chickens. In view of the lack of expertise and basic feed processing equipment, diet dilution with low-cost ingredients may be a viable option for smallholder broiler production in the South Pacific region. More research is needed on the levels of dilution and enzyme concentrations.

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