Feeding Fermented Mixture of Cassava Pulp and *Moringa oleifera* Leaf Meal: Effect on Growth, Internal Organ and Carcass of Broiler Chickens

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Summary

The experiment aimed to evaluate the impact of feeding fermented mixture of cassava pulp and *Moringa oleifera* leaf meal (MOLF) on growth, internal organ and carcass of broilers. The fermented feedstuff was prepared by fermenting the cassava pulp (60%) and MOLF (35%) using the starter of *Chrysonilia crassa* (5%). Four hundred Lohmann broiler chicks (a week of age with initial body weight [BW] of 172 ± 2.50 g) were grouped to CONT (chicks received corn-soybean-based diet), BACI (corn-soybean-based diet supplemented with 0.1% antibiotic), FERM (diet containing 20% of the fermented mixture of cassava pulp and MOLF) and FERB (diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *Bacillus subtilis*). The BW and intake were weekly recorded. At day 35, one chick from each replicate was obtained, slaughtered and de-feathered. The internal organs and carcass were weighed and breast meat was obtained for colour determination. Throughout the study, the variation in body weight gain (BWG) was not observed across the groups, but FERM and FERB had higher ($p<0.05$) consumption and feed conversion ratio (FCR) than CONT and BACI chicks. The abdominal fat pad was lower ($p<0.05$) in FERM and FERB than in BACI group. The lightness values of FERB were lower ($p<0.05$) than that of other meats. The redness values were higher ($p<0.05$) in FERB, while the yellowness values were higher ($p<0.05$) in FERM and FERB than CONT and BACI meats. There were no difference ($p>0.05$) in the carcass yield among the group of diets. In conclusion, feeding the mixture of cassava pulp and MOLF did not compromise growth performance but increased FCR of broiler chickens. Feeding the fermented product lowered abdominal fat weight and improved the colour of broiler meats.

Key words

abdominal fat, broilers, carcass, fermented feed, internal organ, weight gain

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Introduction

Reducing the cost of feed is imperative to ensure the efficient broiler production. The use of alternative feed ingredients could reduce the expense of feed. However, such feed cost saving strategy may often be limited by the low quality of the alternative feedstuffs (Sugiharto, 2019). Among the alternative feedstuffs, cassava pulp produced by tapioca manufacturers may be incorporated in broiler ration as an energy source. Yet, the inclusion of such by-product may be limited to the maximum of 8% (Khempaka et al., 2009) and can be increased up to 16% in broiler rations after fermentation (Khempaka et al., 2014). Fermented feedstuffs have been attributable to the decreased fibre as well as increased protein contents. To further increase the protein level of the fermented feedstuffs, urea (non-protein nitrogen) has commonly been supplemented along with fermentation (Khempaka et al., 2014; Sugiharto et al., 2016, 2017a). Apart from its protein-enhancing effect, the urea supplementation may, however, jeopardize the liver and kidney of chickens especially when the bioconversion of urea into microbial protein is not fully accomplished during the fermentation process (Shahzad et al., 2012; Khempaka et al., 2014).

The mixture of cassava pulp and *Moringa oleifera* leaf meal (MOLF) was fermented using the fungus *Chrysonilia crassa* in the current work. With its fibrolytic capability (Sugiharto et al., 2018a), the fungus *C. crassa* was used as the fermentation starter to degrade the fibre substances in the cassava pulp. To further elevate the level of protein in the cassava pulp-based fermented product, MOLF was mixed with cassava pulp prior to fermentation. This was inspired by the high protein content in the MOLF (Ayasan, 2015; Gopalakrishnan et al., 2016; Ayasan and Ayasan, 2018; Sugiharto et al., 2019a). With the improved nutritional qualities, in the present study the fermented mixture of cassava pulp and MOLF was included at the level of 20% in broiler rations, higher than the maximum safe inclusion (16%) of the fermented cassava pulp in the rations of broilers by Khempaka et al. (2014). The current work aimed to evaluate the impact of feeding fermented mixture of cassava pulp and MOLF on growth, internal organ and carcass characteristics of broilers.

Materials and methods

Preparation of the fermented mixture of cassava pulp and MOLF

The fermentation starter was prepared according to the procedures described by Yudiarti et al. (2019). In brief, the isolate of *C. crassa* was recovered from the stock culture (maintained on potato dextrose agar [PDA] and kept at 4°C). Following the aerobic incubation (38°C, 48 h), the pure fungal isolate was regrown on PDA according to the abovementioned conditions. The fungal spores were collected with 10 mL autoclaved distilled water. This fungal suspension was used for preparing the fermentation starter. Approximately 100 g of the used rice (bought from the local market) was soaked in tap water for 1 h, steamed for 1 h and allowed to cool on tray. The treated used rice was then inoculated with the fungal suspension (10 mL) and aerobically incubated for 48 h at room temperature. The latter product was called as the fermentation starter (containing >1 × 10^8 cfu/g of *C. crassa* colonies) after being sun-dried, milled and sieved.

The dried cassava pulp (moisture content of about 12%) was obtained from the local supplier in Boyolali Regency, Central Java Province, Indonesia. Before use, the cassava pulp was steamed for 1 h and allowed to cool. The *M. oleifera* leaves were collected from the gardens surrounding the campus. The collected leaves were air dried and milled into fine powder before use. To produce the fermented feed ingredient, 60 g of the steamed cassava pulp was mixed thoroughly with 35 g of MOLF. The mixture was then quickly inoculated with the fermentation starter (5 g) and sterilized distilled water (100 mL) was added to gain the water content of approximatelyy 40%. After 72 h of the aerobic incubation at room temperature the fermented mixture was sun dried. The proportions of cassava pulp, MOLF and fermentation starter applied in this study were based on our preliminary work suggesting that the mixture of 60% of cassava pulp, 35% MOLF and 5% starter inoculum produced the best fermented product. The sample of fermented product was taken for laboratory (proximate) analysis (AOAC, 1995) and the rest of the product was placed at room temperature before use for *in vivo* experiment.

In vivo experiment

The *in vivo* experiment was carried out in compliance with the animal ethic standard stated in the Law of the Republic of Indonesia (2009). A number of 400 Lohmann broiler chickens (unsexed) were reared under commercial conditions from days 0 to 7 of age. On day 8, the chicks (body weight [BW] of 172 ± 2.50 g) were randomly grouped to four groups of diets, i.e., CONT (chicks received corn-soybean-based feed without any additive), BACI (chicks received corn-soybean-based diet supplemented with 0.1% zinc bacitracin as an antibiotic growth promoter), FERM (chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF) and FERB (chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *Bacillus subtilis*). Each dietary group consisted of 10 replicates with 10 chicks per replicate. The diets were offered in mash form and prepared as starter (days 8-21, Table 2) and finisher feeds (days 22-35, Table 3). The formulated diets contained no enzymes, antibacterial, antifungal and antiprotozoal agents. The feeds and water were provided to all broiler chicks *ad libitum* until day 35. All birds were immunized with commercial Newcastle disease-infectious bursal (ND-IB) vaccine on day 4 through ocular route and with the IB vaccine on day 14 through drinking water. In addition, the birds were vaccinated using commercial ND vaccine on day 19 of age. During the rearing period, the chicks were kept in an opened-sided broiler house (naturally ventilated) with rice husk as a litter. The BW gain, feed consumption and feed conversion ratio (FCR) were weekly recorded. At day 35, one chick from each replicate was randomly taken, slaughtered and de-feathered. After the evisceration, the selected organs were obtained, emptied and weighed. Also, the carcass percentage and commercial proportions of broilers were determined. Approximately 20 g of the skinless breast muscle were collected for the assessment of meat colour. The determination of the colour values of breast muscle of broilers were conducted according to Sugiharto et al. (2019b). For the measurement digital colour meter in Mac OS X (set to CIE Lab) was used, and values were presented as L* (lightness), a* (redness) and b* (yellowness).

The current experiment was arranged based on a completely randomized design. The data obtained were analysed using ANOVA (SAS Inst. Inc., Cary, NC, USA). When the significant ($p<0.05$) difference was seen across the dietary groups, the Duncan's multiple-range test was then conducted.

Results and discussion

It was apparent in the current work that crude protein was higher in the fermented mixture of cassava pulp and MOLF as compared to that in dried cassava pulp (Table 1). The increased protein content in the fermented mixture of cassava pulp and MOLF seemed to be attributed not only to the high content of protein in MOLF added, but also to the protein enhancing-effect of fermentation using *C. crassa* (Sugiharto et al., 2018a; Yudiarti et al., 2019). Along with the increased crude protein levels, the MOLF supplementation and *C. crassa*-fermentation may also be expected to improve the amino acid compositions of the fermented mixture of cassava pulp and MOLF. Indeed, Moyo et al. (2011) documented that MOLF contained a complete and balanced essential amino acids, which are desirable for the optimal body functions of animals. In line with MOLF supplementation, fungal fermentation may produce fungal biomass protein with high and complete essential amino acids as previously revealed by Ahmed et al. (2017). In this study, the fermented products had lower fibre content when compared with the dried cassava pulp and MOLF. The fibrolytic activity of the fungus *C. crassa* (Sugiharto et al., 2018a) was beneficial in lowering the fibre content in the fermented mixture of cassava pulp and MOLF.

Table 1. Chemical composition of fermented mixture of cassava pulp and MOLF[1]

Composition (%, as dry-basis, unless otherwise stated)	Cassava pulp	MOLF	FCPMO
Moisture	11.0	11.1	8.75
Crude protein	2.24	29.9	17.6
Crude fat	0.91	5.38	4.41
Crude fibre	31.8	13.2	9.01
Ash	3.65	12.6	10.1
Metabolizable energy (kcal/kg)[2]	2,434	2,975	3,170

[1] Analysis was conducted in duplicate, data were not statistically analysed

[2] Metabolizable energy was determined based on formula (Bolton, 1967): 40.81 {0.87 [crude protein + 2.25 crude fat + nitrogen-free extract] + 2.5}

FCPMO: fermented mixture of cassava pulp and MOLF
MOLF: *M. oleifera* leaf meal

Data on the performances of broiler chickens treated with different diets are shown in Table 4. Within the starter phase, feeding the fermented mixture of cassava pulp and MOLF with or without probiotic *B. subtilis* supplementation resulted in lower ($p<0.05$) weight gain than that in control and group treated with zinc bacitracin as antibiotic growth promoter. However, the significant difference in weight gain was not observed ($p>0.05$) during the finisher and the whole period of rearing. This data may indicate that feeding the fermented mixture of cassava pulp and MOLF to reduce the use of yellow corn and soybean meal in the rations did not compromise the overall growth performance of broilers.

Table 2. Ingredients and nutrient compositions (dry-basis) of starter diets

Items (%, unless otherwise noted)	Dietary groups			
	CONT	BACI	FERM	FERB
Yellow corn	54.8	54.8	38.5	38.5
Soybean meal (CP 44%)	35.7	35.7	32.3	32.3
Meat bone meal (CP 40%)	4.70	4.70	4.25	4.25
Soybean oil	1.55	1.55	1.75	1.75
FCPMO	-	-	20.0	20.0
DL-methionine, 990 g	0.30	0.30	0.30	0.30
L-Lysine, 780 g	0.20	0.20	0.20	0.20
Limestone	0.50	0.50	0.50	0.50
Dicalcium phosphate	1.50	1.50	1.50	1.50
Premix[1]	0.50	0.50	0.50	0.50
Salt	0.25	0.25	0.25	0.25
Nutrient compositions:				
Metabolisable energy[2] (kcal/kg)	3,365	3,351	3,272	3,317
Crude protein	18.3	18.4	18.0	18.0
Crude fat	4.87	4.56	3.73	4.59
Crude fibre	7.06	7.06	7.86	7.85
Ash	7.13	7.13	7.53	7.33

[1] Premix contained (per kg of diet) of vit A 7,750 IU, vit D3 1,550 IU, vit E 1.88 mg, vit B1 1.25 mg, vit B2 3.13 mg, vit B6 1.88 mg, vit B12 0.01 mg, vit C 25 mg, folic acid 1.50 mg, Ca-d-pantothenate 7.5 mg, niacin 1.88 mg, biotin 0.13 mg, BHT 25 mg, Co 0.20 mg, Cu 4.35 mg, Fe 54 mg, I 0.45 mg, Mn 130 mg, Zn 86.5 mg, Se 0.25 mg, L-lysine 80 mg, Choline chloride 500 mg, DL-methionine 900 mg, $CaCO_3$ 641.5 mg, Dicalcium phosphate 1500 mg

[2] Metabolizable energy was calculated on the basis of formula (Bolton, 1967) as follow: 40.81 {0.87 [crude protein + 2.25 crude fat + nitrogen-free extract] + 2.5}

CONT: chicks received corn-soybean-based diet without additive, BACI: chicks received corn-soybean-based diet supplemented with 0.1% zinc bacitracin, FERM: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF, FERB: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *B. subtilis*, CP: crude protein, FCPMO: fermented mixture of cassava pulp and MOLF, MOLF: *M. oleifera* leaf meal

In respect to feed consumption, feeding the treatment diet with or without probiotic *B. subtilis* led to increased ($p<0.05$) feed intake of broiler chickens. With the absent difference in weight gain across the dietary groups, the increased feed intake in FERM and FERB consequently increased the FCR and thereby reduced the feed efficiency of corresponding chicks. The reason for the higher feed consumption in FERM and FERB chicks remains unclear, but feeding the fermented products has been suggested to improve the appetite of chicks and palatability of feed (Sugiharto and Ranjitkar, 2019). The relatively high fibre content in the FERM and FERB diets may also contribute to the increase in feed intake of chicks as recently reported by dos Santos et al. (2019).

Table 3. Ingredients and nutrient compositions (dry-basis) of finisher diets

Items (%, unless otherwise noted)	Dietary groups			
	CONT	BACI	FERM	FERB
Yellow corn	58.5	58.5	42.4	42.4
Soybean meal (CP 44%)	32.7	32.7	28.8	28.8
Meat bone meal (CP 40%)	2.35	2.35	2.25	2.25
Soybean oil	3.25	3.25	3.35	3.35
FCPMO	-	-	20.0	20.0
DL-methionine, 990 g	0.30	0.30	0.30	0.30
L-Lysine, 780 g	0.20	0.20	0.20	0.20
Limestone	0.50	0.50	0.50	0.50
Dicalcium phosphate	1.50	1.50	1.50	1.50
Premix[1]	0.50	0.50	0.50	0.50
Salt	0.25	0.25	0.25	0.25
Nutrient compositions:				
Metabolisable energy[2] (kcal/kg)	3,450	3,455	3,440	3,443
Crude protein	16.0	16.1	16.1	16.1
Crude fat	6.09	6.10	6.54	6.54
Crude fibre	7.35	7.35	7.73	7.73
Ash	5.96	5.83	6.44	6.35

[1] Premix contained (per kg of diet) of vit A 7,750 IU, vit D3 1,550 IU, vit E 1.88 mg, vit B1 1.25 mg, vit B2 3.13 mg, vit B6 1.88 mg, vit B12 0.01 mg, vit C 25 mg, folic acid 1.50 mg, Ca-d-pantothenate 7.5 mg, niacin 1.88 mg, biotin 0.13 mg, BHT 25 mg, Co 0.20 mg, Cu 4.35 mg, Fe 54 mg, I 0.45 mg, Mn 130 mg, Zn 86.5 mg, Se 0.25 mg, L-lysine 80 mg, Choline chloride 500 mg, DL-methionine 900 mg, $CaCO_3$ 641.5 mg, Dicalcium phosphate 1500 mg

[2] Metabolizable energy was calculated on the basis of formula (Bolton, 1967) as follow: 40.81 {0.87 [crude protein + 2.25 crude fat + nitrogen-free extract] + 2.5}

CONT: chicks received corn-soybean-based diet with no additive, BACI: chicks received corn-soybean-based diet supplemented with 0.1% zinc bacitracin, FERM: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF, FERB: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *B. subtilis*, CP: crude protein, FCPMO: fermented mixture of cassava pulp and MOLF, MOLF: *M. oleifera* leaf meal

Also, probiotic *B. subtilis* seemed to increase feed intake due to the improvement in the intestinal morphology of broilers (Abudabos et al., 2019). In most cases, the increased feed consumption is accompanied with the increased weight gain of broilers. Yet, such condition was not found in the present study, indicating that FERM and FERB chicks had lower nutrient utilization when compared with the chicks in CONT and BACI groups. Similar finding was reported by dos Santos et al. (2019) documenting that higher feed intake was not in parallel with the increased body weight gain of broiler chickens. The latter work inferred that the high fibre level in diets may be responsible for the reduced nutrient digestibility and thus growth rate of broilers (Jimenez-Moreno et al., 2009; dos Santos et al., 2019).

Data on organ relative weight of broilers are listed in Table 5. It was apparent that the abdominal fat deposition was lower ($p<0.05$) in FERM and FERB groups than in BACI group. Formerly, dietary incorporation of cottonseed meal fermented using *Candida tropicalis* and *Saccharomyces cerevisiae* resulted in lower abdominal fat pad as reported by Nie et al. (2015). According to Sugiharto and Ranjitkar (2019), the decrease in abdominal fat deposition in broilers fed fermented products was mainly attributable to the increased β-oxidation of fatty acids as well as the hydrolysis of triglycerides. In our case, probiotic microorganisms seemed also to contribute in reducing the abdominal fat weight of broilers in the FERM and FERB groups. This was supported by the study of Safalaoh (2006), showing the lowered abdominal fat deposit in broiler chickens fed probiotics. In this study, the mixture of cassava pulp and MOLF was fermented with the fungus C. *crassa* that formerly documented to possess probiotic properties (Sugiharto et al., 2017b; 2018b). The decreased abdominal fat content was also most likely due to the higher fibre content in the diets of FERM and FERB birds (Table 2 and 3). Indeed, Sadeghi et al. (2015) reported that high level of dietary fibre decreased the fat deposition in the abdomen of broiler chickens. This was due to the capability of fibre in binding the bile salts produced from cholesterol and thereby to reduce the deposition of fat in the abdomen of chickens.

In this study, the eviscerated carcass and commercial proportions of chicks did not vary ($p>0.05$) across the dietary treatment groups (Table 6). This indicated that feeding the fermented mixture of cassava pulp and MOLF resulted in no detrimental impact on the carcass traits of broilers. In contrast, Khempaka et al. (2009) showed that feeding dried cassava pulp at the level of 16% resulted in lower thigh meat of broilers. Relative to the eviscerated carcass, the proportion of abdominal fat of FERM and FERB was lower ($p<0.05$) when compared with that particularly with BACI chicks. This may, therefore, suggested that feeding the fermented mixture of cassava pulp and MOLF with or without probiotic *B. subtilis* supplementation improved the carcass quality of broilers as indicated by the lower abdominal fat weight. In agreement, feeding *Acremonium charticola*-fermented cassava pulp decreased the abdominal fat content of broiler chickens in the study of Sugiharto et al. (2017b). The reasons by which the fermented product lowered the abdominal fat content of broilers have already been discussed in the previous paragraph. With regard particularly to MOLF, this green leaf seemed also to possess fat-reducing properties as reported by Cui et al. (2018). They confirmed that feeding MOLF decreased the abdominal fat content of broiler chickens. The latter authors also inferred that MOLF may reduce lipid synthesis and activate fatty acid β-oxidation (i.e., by increasing the concentration of polyunsaturated fatty acids) resulting in less fat deposition in the body of broiler chickens.

Data on the colour values of breast muscle of broiler chicks are shown in Table 7. Apparently, the lightness values of FERB breast meat were lower ($p<0.05$) than those of other meat samples. Mir et al (2017) documented that the decreased lightness values in broiler meat is generally attributed to the increased concentration of myoglobin or heme pigment in the meat as well as the minimal protein denaturation post slaughtering. The latter condition therefore results in the increased redness and yellowness values of meat. Indeed, the redness values were higher ($p<0.05$) in FERB

Table 4. Production traits of broiler chicks fed treatment diets

Items (%, unless otherwise noted)	Dietary groups				SE	p value
	CONT	BACI	FERM	FERB		
Initial BW (g)	170	174	169	174	1.72	0.14
Days 8-21						
Weight gain (g/d)	587^{ab}	607^{a}	568^{b}	565^{b}	10.6	0.03
Accumulative FI (g/d)	832^{c}	847^{c}	880^{b}	907^{a}	6.68	<0.01
FCR	1.42^{b}	1.40^{b}	1.55^{a}	1.61^{a}	0.03	<0.01
Days 22-35						
Weight gain (g/d)	1,101	1,059	1,076	1,023	32.1	0.38
Accumulative FI (g/d)	1,985^{b}	1,956^{b}	2,231^{a}	2,223^{a}	34.1	<0.01
FCR	1.81^{b}	1.86^{b}	2.11^{a}	2.18^{a}	0.07	<0.01
Days 8-35						
Weight gain (g/d)	1,688	1,666	1,644	1,587	31.3	0.15
Accumulative FI (g/d)	2,848^{b}	2,802^{b}	3,110^{a}	3,130^{a}	42.6	<0.01
FCR	1.69^{b}	1.68^{b}	1.91^{a}	1.98^{a}	0.04	<0.01

^{a,b} Means with various letters within the similar row indicate substantial difference.

CONT: chicks received corn-soybean-based diet without additive, BACI: chicks received corn-soybean-based diet supplemented with 0.1% zinc bacitracin, FERM: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF, FERB: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *B. subtilis*, MOLF: *M. oleifera* leaf meal, SE: standard error, FI: feed intake, BW: body weight, FCR: feed conversion ratio

Table 5. Organs weight of broiler chicks fed treatment diets

Items (% live BW)	Dietary groups				SE	*p* value
	CONT	BACI	FERM	FERB		
Heart	0.51	0.54	0.49	0.50	0.02	0.36
Liver	2.29	2.24	2.20	2.17	0.10	0.85
Proventriculus	0.39	0.39	0.36	0.36	0.02	0.36
Gizzard	1.51	1.59	1.53	1.56	0.05	0.64
Spleen	0.12	0.15	0.12	0.19	0.03	0.33
Thymus	0.30	0.30	0.35	0.32	0.03	0.73
Bursa of Fabricius	0.06	0.07	0.07	0.06	0.01	0.83
Duodenum	0.51	0.50	0.52	0.56	0.04	0.77
Jejunum	1.25	1.30	1.38	1.39	0.06	0.33
Ileum	0.87	0.99	0.96	0.96	0.05	0.39
Caeca	0.51	0.57	0.51	0.52	0.03	0.37
Abdominal fat	1.18^{ab}	1.26^{a}	0.90^{b}	0.91^{b}	0.10	0.03

^{a,b} Means with various letters within the similar row indicate substantial difference.

CONT: chicks received corn-soybean-based diet without additive, BACI: chicks received corn-soybean-based diet supplemented with 0.1% zinc bacitracin, FERM: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF, FERB: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *B. subtilis*, MOLF: *M. oleifera* leaf meal, SE: standard error, BW: body weight

Table 6. Carcass traits of broiler chicks fed treatment diets

Items	Dietary groups				SE	*p* value
	CONT	BACI	FERM	FERB		
			(% live BW)			
Eviscerated carcass	67.5	69.4	67.2	67.8	1.82	0.84
			(% eviscerated carcass)			
Breast	36.0	36.6	36.5	36.8	0.65	0.83
Thigh	15.9	15.7	15.6	15.3	0.36	0.75
Drumstick	13.9	14.1	14.2	14.9	0.33	0.18
Wings	11.3	10.8	11.7	11.2	0.23	0.08
Back	22.9	22.9	22.0	21.8	0.75	0.63
Abdominal fat	1.74^{ab}	1.81^{a}	1.35^{b}	1.36^{b}	0.14	0.04

^{a,b} Means with various letters within the similar row indicate substantial difference.

CONT: chicks received corn-soybean-based diet without additive, BACI: chicks received corn-soybean-based diet supplemented with 0.1% zinc bacitracin, FERM: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF, FERB: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *B. subtilis*, MOLF: *M. oleifera* leaf meal, SE: standard error, BW: body weight

Table 7. Colour values of breast meats of broiler chicks fed treatment diets

Items (% live BW)	Dietary groups				SE	*p* value
	CONT	BACI	FERM	FERB		
L* (lightness)	46.1^{a}	47.7^{a}	47.0^{a}	43.2^{b}	0.60	<0.01
a* (redness)	9.85^{b}	8.08^{c}	10.4^{b}	14.0^{a}	0.55	<0.01
b* (yellowness)	26.7^{b}	26.8^{b}	29.1^{a}	28.8^{a}	0.44	<0.01

^{a,b,c} Means with various letters within the similar row indicate substantial difference.

CONT: chicks received corn-soybean-based diet without additive, BACI: chicks received corn-soybean-based diet supplemented with 0.1% zinc bacitracin, FERM: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF, FERB: chicks received diet containing 20% of the fermented mixture of cassava pulp and MOLF and supplemented with 0.1% probiotic *B. subtilis*, MOLF: *M. oleifera* leaf meal, SE: standard error

breast meat than in other breast muscles, while the yellowness values were higher ($p<0.05$) in FERM and FERB than in CONT and BACI breast meats in the present study. This eventually suggested that feeding 20% of the fermented mixture of cassava pulp and MOLF supplemented with 0.1% probiotic *B. subtilis* may contribute to the improvement of meat quality of broiler chickens. The mechanisms through which fermented feed improved the colour of broiler meats remains unclear, but it seemed that feeding fermented feed improved the oxidative stability (due to the increased antioxidants concentration in meats), which is attributed to the decreased lightness and increased redness values of broiler meats (Kim and Kang, 2016; Kim et al., 2016). In respect to MOLF, the high content of antioxidants in the MOLF seemed also to contribute to the increased oxidative stability attributing to the reduced lightness and increased redness and yellowness values of broiler meats (Nkukwana et al., 2016). Moreover, the supplementation of probiotic *B. subtilis* was also most likely to contribute to the decreased lightness and increased redness values of broiler meats as formerly reported by Pelicano et al. (2003). Such probiotic supplementation may increase the ultimate pH of broiler meats and thereby alleviating the myofibrillar proteins damage.

Conclusion

Feeding the fermented mixture of cassava pulp and MOLF did not compromise growth performance but increased the FCR of broiler chickens. Feeding such diet lowered the abdominal fat deposition and improved the colour of broiler meats.

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Conflict of interests

The authors had no conflict of interest.

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