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Use of Organic Acid, Herbs and Their Combination to Improve the Utilization of Commercial Low Protein Broiler Diets

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Abstract: Two experiments were conducted to investigate the growth performance, carcass characteristics, organ weights, plasma proteins and fecal N excretion in broilers fed a 18% crude protein diet supplemented with *Thymus vulgaris*, *Curcuma longa*, citric acid, lactic acid or their combinations. In the first experiment, 98 broiler chicks were fed a control diet or a control diet with 0.2% Thyme (TH), 0.2% *Curcuma longa* (CL), 0.2% Citric acid (CIT), 0.2% TH + 0.2% CL, 0.2% TH + 0.2% CIT, 0.2% CL + 0.2% CIT. In the second experiment, 98 broiler chicks were fed a control diet with 0.2% TH, 0.2% lactic acid (LAC), 0.2% CIT, 0.2% TH + 0.2% LAC, 0.2% TH + 0.2% CIT, 0.1% LAC + 0.1% CIT. Addition of 0.2% TH, or TH + CIT increased weight gain in 21 day-old birds in experiment 1 ($p<0.05$). Addition of supplements did not produce any significant increase in day 42 body weight. No significant effect of supplements on carcass characteristics, feed conversion, plasma proteins or organ weights were observed except for liver which was higher in birds fed CIT (experiment 1) ($p<0.05$). No difference was observed in the total protein, albumen or globulin in the plasma. No difference was noticed between dietary treatments on the percentage of fecal Nitrogen (N), AME or Nitrogen retention (NR). Although not significant, the birds fed TH + CL excreted 12.9% less fecal N than Control birds. Similarly, the NR was 13.25% higher in TH + CL when compared with Control birds. Considering the role of low protein diets in reducing feed cost and fecal N excretion, further studies are needed to evaluate the role of plant extracts and organic acids and their optimal levels for broiler birds fed a low protein diet that are raised under suboptimal commercial conditions.

Key words: Organic acid, herbs, broilers

INTRODUCTION

The excretion of Nitrogen (N) originating from intensive livestock and poultry operation is one of the greatest environmental concerns to the public. In addition to polluting the air and water, N in poultry excreta or litter is converted to volatile ammonia through microbial fermentation and can affect the health of birds and farm workers (Nahm, 2007; Headon and Dawson, 1990). Approximately, 70-75% of the N consumed by animals is lost or excreted due to the inefficiencies associated with protein digestion and or absorption (Parsons, 1995; Nahm, 2007). Schutte *et al.* (1993) reported that for each percentage of N decrease in the feed, N excretion is reduced by 10%. In response, dietary means to decrease N excretion by feeding low Crude Protein (CP) diets to poultry has been reported (Parsons, 1995; Aletor *et al.*, 2000). However, feeding low protein diets has been reported to affect growth performance and carcass yield of broiler chickens (Bregendahl *et al.*, 2002).

The removal of antibiotic growth promoters from poultry diets necessitate search for natural alternatives as replacements in growing flocks, especially under conditions of average management and quality. Most supplements that are used as alternatives to antibiotics in poultry production such as plant materials or extracts such as herbs, essential oils, spices, probiotics, prebiotics and organic acids, have effects on microflora, either directly or indirectly (Richards *et al.*, 2005). For example, the phenolic compounds (carvacrol and thymol) present in the essential oil from *Thymus vulgaris* exhibit antimicrobial and antifungicidal activity (Basilico and Basilico, 1999). *Curcuma longa* has been found to have anti-inflammatory and anti-infectious properties (Allen *et al.*, 1998) and citric acid has been reported to inhibit bacterial growth (Roe *et al.*, 1998). In addition, plant extracts and herbs have been reported to activate the immune system (Chang *et al.*, 1995; Barak *et al.*, 2001). Addition of citric acid and *Curcuma longa* in rabbit diet decreased plasma globulin and harmful microorganisms in the caecum while improving growth (Ali *et al.*, 2008). Gram positive bacteria are generally more sensitive to essential oils than gram-negative bacteria (Smith-Palmer *et al.*, 1998). Therefore, addition of herbs to citric acid that has a disrupting effect on gram negative bacteria (Ocana-Morgner and Dankert 2001), may have added beneficial effect on broiler performance and N utilization. Moreover, the antioxidant properties of natural antioxidants like *Thymus vulgaris* or *Curcuma longa* may decrease reactive oxygen species thereby decreasing protein oxidation affecting bird growth and N excretion. Although, antimicrobial effects of plant extracts have been demonstrated *in vitro*, their influence on growth performance of broiler birds fed low protein diet is not known. In this context, the objectives of the current study was to investigate the growth performance, carcass characteristics, plasma proteins and fecal N excretion in broilers fed a low CP diet supplemented with *Thymus vulgaris* , *Curcuma longa*, citric acid, lactic acid or their combination.

MATERIALS AND METHODS

Birds, diet and housing: Two experiments were conducted at Oregon State University, Corvallis, Oregon, USA. A total of 196 birds were used for experiment 1 and experiment 2. For each experiment, a total of 98 birds were used. In experiment 1, one day-old unsexed Cobb broiler chicks were purchased from a local commercial hatchery and in experiment 2, day-old chicks were obtained from the Oregon State University, poultry farm hatchery. The average weight of chicks in experiment 1 and 2 were 44.9±1.9 and 47.9±1.3 g, respectively. The chicks were randomly divided equally to 7 experimental treatments. Each treatment had 2 replicates of 7 chicks. Chicks of each replicate were housed in individual floor pens with deep litter and were fed the experimental diet for a period of 42 days. For experiment 1 and 2, a commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri) was used as the Control. The Control diet was supplemented with 0.2% Thyme (TH), 0.2% *Curcuma longa* (CL), 0.2% citric acid (CIT), 0.2% TH + 0.2% CL, 0.2% TH + 0.2% CIT, 0.2% CL+0.2% CIT in Experiment 1 (Table 1). In experiment 2, Control diet was supplemented with 0.2% TH, 0.2% Lactic Acid (LAC), 0.2% CIT, 0.2% TH + 0.2% LAC, 0.2% TH +0.2% CIT, 0.1% LAC + 0.1% CIT (Table 1). The Control diet was corn, wheat, wheat middlings and soybean meal-based and had 18% CP and 2900 ME Kcal/Kg. Chemical analysis of the Control diet was done at the University of Arkansas Poultry Science Central Analytical Laboratory and is presented in Table 2. Feed and water were provided to the birds *ad libitum*. The lighting regime throughout the study was 23L:1D. During the 2 experiments, records were kept individually on live weights on day 21 and 42. Feed intake/pen basis was measured to calculate Body Weight Gain (BWG) and Feed Conversion (FC).

Sample collection and analytical aspects: Fecal digestibility trial was conducted at the end of the experiment 1. Feed intake and excreta voided were recorded during the last 3 days. The collected excreta was sprayed with 2% boric acid solution to prevent ammonia loss and was dried in an oven at 60°C for 24 h, weighed and was finely ground. Feed and the finely ground excreta was analyzed for Gross Energy (GE) and N content at the University of Arkansas Poultry Science Central Analytical Laboratory. Nitrogen retention (NR %) was calculated from the following formula:

$$\text{NR (\%)} = \frac{\text{N content of dry feed-N content of dried excreta}}{\text{N content of dry feed}} \times 100$$

Apparent Metabolizable Energy (AME) was calculated by subtracting GE of dried excreta from GE of dried feed. For experiment 1 and 2, at 42 days of age, 3 birds with the nearest average live body weight was randomly selected from each treatment and were deprived of feed for 16 h prior to slaughtering. The birds were weighed and were exsanguinated. Birds were transferred to restraining cones and were bled for 90 sec, scalded at 54°C for 120 sec and mechanically defeathered for 30 sec. Feet were removed manually by severing the intra tarsal joint. Carcasses were manually eviscerated and abdominal fat, liver, gizzard, heart (experiment 2 only) and giblets were removed and were weighed to calculate organ weights, carcass weights, total edible parts and abdominal fat percentages. Blood samples were collected (3 birds from each treatment) in experiment 1 and was assayed for plasma protein, albumin and globulin at the Oregon State University, College of Veterinary Medicine animal health laboratory.

Statistical analysis: The effects of diet on bird performance, carcass characteristics, plasma proteins, organ weights and fecal N, AME and NR were analyzed by one-way ANOVA using the General Liner Model procedure of SAS (version 6.04) (SAS Institute, 1994). Significant differences among treatment means were separated using Duncan (1955) Multiple Range Test. The statistical model used for analyzing data obtained was:

$$Y_{ij} = M + T_i + E_{ij}$$

where:

Y_{ij} = The individual observation
M = The overall mean
T_i = The effect of supplementation
E_{ij} = The experimental error

RESULTS AND DISCUSSION

Growth performance: In experiment 1, during the starter period (day 1-day 21), the birds fed Control diet supplemented with CIT had the lowest gain while those fed Control diet with TH and TH +CIT had the highest weight gain ($p<0.05$). However, during the finisher period (day 22-day 42), birds fed CIT recorded the highest BWG, while those fed the mixture of CIT + CL recorded the lowest ($p<0.05$) (Table 3). No difference was found in the BWG during the overall period, or FC during starter, finisher or during the entire period for experiment 1 ($p>0.05$). A beneficial effect of TH + CIT when compared to CIT was observed in the starter period of experiment 1. The increase in BWG in TH + CIT may be due to a synergistic effect (Ali *et al.*, 2008). Plant extracts and organic acids could control and limit the growth

Table 1: The experimental treatments

	Experiment # 1		Experiment # 2	
Treatment #	Supplement*	Inclusion rate	Supplement*	Inclusion rate
T1	TH	0.2%	TH	0.2%
T2	CL	0.2%	LAC	0.2%
T3	CIT	0.2%	CIT	0.2%
T4	TH+CL	0.2%+0.2%	TH+LAC	0.2%+0.2%
T5	TH+CIT	0.2%+0.2%	TH+CIT	0.2%+0.2%
T6	CL +CIT	0.2%+0.2%	LAC+CIT	0.1%+0.1%
T7	Control	None	Control	None

TH = Thyme, CL = *Curcuma longa,* CIT = Citric Acid, LAC = Lactic Acid, Control = Corn-soy-wheat based commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri)

Table 2: Chemical composition of control diet

	Calculated		
Parameters	Min.	Max.	Determined
Crude protein (%)	18.00		17.8
ME (kcal/kg)	2932		
GE (kcal/kg)			3918
Crude fat (%)	3.00		3.63
Crude fiber (%)		5.00	
ADF (%)			4.27
NDF (%)			14.79
Ash (%)			5.85
Lysine (%)	0.88		
Methionine (%)	0.32		
Calcium (%)	0.75	1.25	
Phosphorus (%)	0.60		
Salt (%)	0.35		
Sodium (%)	0.10		
Vitamin A (IU/kg)	11023		
Vitamin E (IU/kg)	30		

All available informations of diet composition obtained from purina Mills LLC, as listed below. Ingredients: Ground corn, dehulled soybean meal, ground wheat, wheat middlings, safflower, calcium carbonate, monocalcium phosphate, dicalcium phosphate, cane molasses, salt, DL-methionine, L-lysine, choline chloride, riboflavin, vitamin E, calcium pantothenate, taeget extract, vitamin B-12, biotin, vitamin A, menadione dimethylpyrimidinolbisulfite, folic acid, pyridoxine hydrochloride, niacin, vitamin D3, manganous oxide, zinc oxide, copper sulfate, calcium iodate, sodium selenite

and colonization of numerous pathogenic and non-pathogenic species of bacteria in the gut. It has been reported that gram positive bacteria are more sensitive to essential oil compounds (Smith-Palmer *et al.,* 1998). Although mechanistic aspects of herbs and essential oils are not clearly understood, citric acid (CIT) can disrupt the membrane integrity of the organic matter of gram-negative bacteria affecting their survival (Ocana-Morgner and Dankert, 2001). Therefore, a combination of TH + CIT through their synergistic effect may be a promising additive that could be used in commercial broiler farms.

The improvement in BWG in CIT-fed birds during finisher period in experiment 1 may be due to the effect of CIT on the utilization of minerals affecting growth. Low-protein diet has been reported to impair calcium absorption (Kerstetter *et al*., 2003). Dietary CIT may decrease intestinal pH and increase Ca availability. Citric acid addition to broiler diets has been reported to improve tibia ash without reducing weight gain or feed intake (Snow *et al.,* 2004). In addition, the utilization phytate P and trace minerals were also improved by citric acid upon feeding low CP diet (Boling *et al.,* 2000; Klavins *et al.,* 1962). The basal diet used in the current study contained corn, ground wheat and wheat middling that are rich in phytate P that can affect mineral absorption. Therefore, addition of CIT may compliment diets that are high in phytate P. Although not significantly different, birds fed TH + CIT had the highest weight gain while the birds fed CL + CIT had the lowest weight gain during the entire period in experiment 1. The addition of TH + CIT or CIT to Control diet increased the weight gain by 5.22 and 3.17%, respectively. In the current study, a low number of birds (14/treatment) were used. Further research with large number of birds to evaluate bird performance with added herbs or organic acid is needed.

In experiment 2, no differences in weight gain, or feed conversion due to the addition of various supplements was observed during the starter or finisher period. The diets used in experiment 1 and 2 were lower in CP% and ME than the suggested requirements for Cobb. However, the overall growth of birds in all the treatments was similar to standard body weight of Cobb strain. Controversial results have been reported on the effect of feeding low CP diet compared to the standard 23% CP diet to broilers. Reduction in growth and an increase in feed/gain ratio in birds fed low protein diets were reported (Bregendahl *et al.,* 2002; Si *et al.,* 2004a, b). However, Waldroup (2000) and Sterling *et al.* (2005) reported that growth performance was not affected as the CP level was decreased below 20%. The reported discrepancies in dietary CP content and bird performance may be due to other factors such as management and hygiene. For e.g., microflora-specific immunoglobulin secretion can reduce muscle protein deposition affecting BWG. Furthermore, bacteria compete with the host for uptake of amino acids, thereby reducing nitrogen utilization (March *et al.,* 1978; Furuse and Yokota, 1985) and can ferment amino acids, producing toxic metabolites (e.g., amines and phenols

Table 3: Effect of dietary treatments on weight gain and feed conversion in experiment 1

Dietary treatment	GS (g) *	GF (g) *	GT (g)*	FCS*	FCF*	FCT*
TH	721[a]	1592[abc]	2313	1.55	2.19	1.99
CL	675[ab]	1547[bc]	2222	1.56	2.18	1.99
CIT	646[b]	1722[a]	2369	1.64	2.11	1.98
TH + CL	678[ab]	1587[abc]	2264	1.59	2.09	1.94
TH + CIT	732[a]	1684[ab]	2416	1.59	2.16	1.98
CL+ CIT	685[ab]	1525[c]	2210	1.57	2.18	1.99
Control	709[ab]	1586[abc]	2296	1.56	2.22	2.02
Pooled SEM	20.85	50.93	70.36	0.07	0.08	0.07

[a-c]Means in the same column with different letters, differ significantly ($p \leq 0.05$). *GS = Gain during starter period, GF = Gain during finisher period. *GT = Gain during overall period, FCS = Feed conversion during starter period. *GF = Gain during finisher period, FCT = Feed conversion during overall period. TH = Thyme, CL = *Curcuma Longa,* CIT = citric acid, LAC = lactic acid, Control = Corn, soy, wheat-based commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri) and supplements added at 0.2% in the different treatments. Pooled SEM = Pooled standard error mean

Table 4: Effect of dietary treatments on carcass characteristics in experiment 1

Item	Carcass (%)	Liver (%)	Gizzard (%)	Abdominal fat (%)	Total edible parts (%)	Giblets (%)
TH	69.94	1.68	0.83	1.40	72.92	2.98
CL	67.22	1.69	0.72	1.90	70.05	2.83
CIT	68.13	1.68	0.78	1.89	71.07	2.93
TH + CL	68.68	1.65	0.81	1.49	71.56	2.88
TH + CIT	69.66	1.56	0.74	1.65	72.35	2.68
CL+ CIT	68.78	1.56	0.91	1.91	71.68	2.89
Control	68.83	1.66	0.74	1.95	71.66	2.82
Pooled SEM	1.16	0.08	0.08	0.27	1.06	0.15

TH = Thyme, CL = *Curcuma longa,* CIT = Citric Acid, Control = Corn-soy-wheat based commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri) and supplements added at 0.2% in the different treatments. Pooled SEM = Pooled standard error mean

and indoles) which can affect intestinal cell turnover and growth performance (Ewing and Cole, 1994; Gaskins, 2001; Vander Klis and Jansman, 2002). The average FC values during overall period (FCT) in this study was 1.98 and 1.95 for experiment 1 and 2 and was much higher than the FCT for Cobb strain (1.75) at 42 days of growth. The high FCT observed in the current study may be due to increase in feed intake associated with low diet CP and ME intake than what is required for Cobb birds. Although not significantly different, addition of supplements tended to reduce FC by 1.98% compared to the Control birds in experiment 1. It has been reported that herbal oil extracts improved the secretion of digestive enzymes, AME and AMEn in birds (William and Losa (2001), Jang *et al.* (2004, 2007) and Cross *et al.* (2004).

The lack of minimal response in experiment 2 to feed additives is not clearly known. Both experiments were conducted under optimal management and hygienic conditions in a University poultry farm. It has been documented that antibiotic growth promoters or essential oil may not give beneficial effects when birds are kept in clean hygienic conditions and when fed highly digestible diets (Jang *et al.,* 2007). The chick source and their initial body weight may also affect growth performance. In experiment 1, chicks were obtained from a commercial hatchery and in experiment 2, chicks were hatched at the Oregon State University, poultry farm. The hatch weight for second experiment was 7.14% higher when compared with hatch weight of chicks in experiment 1. Although, the Control diet was the same for both experiments, the difference in initial hatch weight is reflected in the weight gain during the starter period in experiment 2. The higher weight of chicks in the second experiment during early growth and the lack of response to supplements suggest that use of additives may be beneficial in low weight chicks.

Carcass and organ weights: No differences were noticed for carcass, liver, gizzard, abdominal fat, total edible parts and giblets in experiment 1. However, in experiment 2, birds fed CIT had higher liver weight percent compared to the other treatments. No effect of diet was noticed in the carcass or organ weight of any other parameters in experiment 2. It is not known if the CIT influenced hepatic metabolism in birds fed a low CP diet to affect the liver weight. It has been reported that water-soluble extract from rosemary enhanced hepatic metabolism and increased liver weight in rats (Debersac *et al.*, 2001). However, other studies in broilers have reported no effects of plant extracts on organ weights (Hernandez *et al.*, 2004).

Digestibility and nitrogen retention: In general, no difference was noticed between dietary treatments on the percentage of fecal N, AME or NR%. Although not significant, the birds fed TH + CL excreted 12.9% less fecal N than Control birds. Similarly, the NR was 13.25%

Table 5: Effect of dietary treatments on N content in feces, apparent metabolizable energy and Nitrogen retention

	TH	CL	CIT	TH + CL	TH +CIT	CL + CIT	Control
N (%)	4.55±0.10	4.55±0.27	4.27±0.19	3.92±0.10	4.32±0.05	4.12±0.03	4.50±0.30
AME	3064±65.75	2987±42.52	2977±56.04	3054±32.29	2963±17.26	2985±59.99	2949±109.80
NR (%)	52.73±3.14	49.32±3.35	51.87±3.54	58.17±1.00	51.39±0.36	54.50±1.43	51.36±4.12

Means±standard error. TH = Thyme, CL = *Curcuma longa,* CIT = Citric Acid, LAC = Lactic Acid, Control = Corn-soy-wheat based commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri) and supplements added at 0.2% in the different treatments. NR = Nitrogen Retention

Table 6: Effect of dietary treatments on some plasma parameters

Parameter	TH	CL	CIT	TH +CL	TH +CIT	CL +CIT	Control
Total protein (g/dL)	2.43±0.06	2.66±0.17	2.46±0.06	2.65±0.05	2.56±0.06	2.63±0.03	2.43±0.17
Allumin (g/dL)	1.16±0.03	1.26±0.06	1.20±0.05	1.25±0.05	1.23±0.08	1.30±0.00	1.13±0.06
Globulin (g/dL)	1.26±0.03	1.40±0.11	1.26±0.03	1.40±0.001	1.33±0.03	1.33±0.03	1.30±0.11

TH = Thyme, CL = *Curcuma longa,* CIT = Citric Acid, LAC = Lactic Acid, Control = Corn-soy-wheat based commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri) and supplements added at 0.2% in the different treatments. Means±standard error

Table 7: Effect of dietary treatments on weight gain and feed conversion in experiment 2

Treatments	GS*	GF*	GT*	FCS*	FCF*	FCT*
TH	780	1506	2287	1.63	2.12	1.91
LAC	760	1474	2235	1.66	2.14	1.95
CIT	790	1558	2348	1.67	2.09	1.94
TH + LAC	769	1593	2363	1.71	2.10	1.95
TH + CIT	758	1541	2299	1.75	2.08	1.95
LAC + CIT	753	1580	2333	1.70	2.24	2.00
Control	801	1521	2322	1.66	2.19	1.98
Pooled SEM	23.75	80.17	78.76	0.06	0.13	0.07

TH = Thyme, CL = *Curcuma longa,* CIT = Citric Acid, LAC = Lactic Acid, Control = Corn-soy-wheat based commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri). Pooled SEM = Pooled standard error mean. *GS = Gain during starter period, *GF = Gain during finisher period. *GT = Gain during overall period, *FCS = Feed conversion during starter period. *GF = Gain during finisher period, *FCT = Feed conversion during overall period

Table 8: Effect of dietary treatments on carcass characteristics in experiment 2

Treatment	Carcass (%)	Liver (%)	Heart (%)	Gizzard (%)	Abdominal fat (%)
TH	71.37	1.84^{b}	0.40	0.75	1.52
LAC	70.84	1.76^{b}	0.38	0.92	1.75
CIT	69.90	2.28^{a}	0.37	0.85	1.66
TH + LAC	72.04	1.53^{b}	0.33	0.70	1.77
TH + CIT	68.87	1.58^{b}	0.42	0.87	1.23
LAC + CIT	71.74	1.83^{b}	0.41	0.91	2.00
Control	70.70	1.89^{b}	0.42	0.81	1.93
Pooled SEM	0.73	0.06	0.01	0.03	0.08

TH = Thyme, CL = *Curcuma longa,* CIT = Citric Acid, LAC = Lactic Acid, Control = Corn-soy-wheat based commercial diet (Start and Grow Sunfresh Recipe; Purina Mills, Missouri). $^{a-b}$Means in the same column with different letters, differ significantly ($p \leq 0.05$). Pooled SEM = Pooled standard error mean

higher in TH + CL when compared with Control birds. The decrease in fecal N in TH + CL may be due to the synergistic effect of thyme and *Curcuma longa* on microbes which improved feed conversion and reduced N content in feces thereby increasing NR. It has been reported that inclusion of chestnut wood extract in broiler diets reduced total N in the litter (Schiavone *et al.*, 2008). Bacteria compete with host for uptake of amino acids, thereby reducing N utilization (March *et al.*, 1978; Furuse and Yokota, 1985). In addition, thyme and *Curcuma longa* have antioxidant properties that may decrease the reactive oxygen species and consequently decrease the protein damage thereby increasing N lost in feces. Addition of thyme alone or in combination with *Curcuma longa* numerically increased the AME (Table 5). The increase in AME upon feeding thyme and *Curcuma longa* may be associated with improvement in the secretion of digestive enzymes. It has been reported that incorporation of essential oil extracted from thyme in poultry diets improved the secretion of digestive enzyme thereby increasing AME compared to diets without thyme oil (Jang *et al.*, 2007; Cross *et al.*, 2004).

Plasma proteins: No difference was observed in the total protein, albumen or globulin in the plasma (Table 6). Addition of 0.2% *Curcuma longa* + 0.2% citric acid in rabbit diet has been reported to reduce plasma globulin (Ali *et al.*, 2008). However, the lack of any effect of *Curcuma longa* and citric acid in the current study may be due to species difference suggesting that the effects of plant extracts are species-specific.

Conclusion: Addition of 0.2% TH, or TH with CIT increased weight gain in 21 day-old birds. The effect of different supplements did not produce any significant increase in day 42 BWG in birds. Although not significantly different, addition of TH + CL decreased N% in feces and increased NR% compared with the Control diet. No significant effect of supplements on carcass characteristics, feed conversion, plasma proteins or organ weights were observed except for liver weight which was higher in CIT. In the current study, small numbers of birds were used and the birds were raised in a clean, hygienic, University farm under optimal conditions. Considering the role of low protein diets in reducing feed cost and fecal N excretion, further studies are needed to evaluate the role of plant extracts and organic acids and their optimal levels for broiler birds fed a low protein diet that are raised under suboptimal commercial conditions.

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