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Production Performance, Meat Quality and Economic Appraisal of Broiler Rearing with Tamarind Leaves

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ABSTRACT

The study was carried out to investigate the effects of Tamarind tree leaves with dry and fermentation using beneficial bacteria on growth performance, carcass characteristics, meat oxidative stability and economics of broiler rearing. A total of 90 day-old Ross-308 unsexed broiler chicks were assigned to three dietary treatments consisting of three replications having 10 birds in each for 4 weeks in a completely randomized design. Dietary treatments were, T_0 = Control (basal diet), T_1 (basal diet + 0.4% dried Tamarind tree leaves on DM basis) and T_2 (basal diet + 0.4% fermented Tamarind leaves on DM basis). According to the results, overall average daily gain (ADG) were increased and feed conversion ratio (FCR) improved in both T_1 and T_2 groups compared to the control group ($P<0.05$). A significant increased HDL level and decreased LDL, total cholesterol and triglyceride level in all treatment groups relative to control ($P<0.05$). Crude protein (CP) and ether extract (EE) content of breast meat was higher ($P<0.05$) in T_2 group than control and T_1 groups. Relative breast meat and heart weight was found higher while decreased abdominal fat weight ($P<0.05$) in treatment groups compared to the control group. In addition, thiobarbituric acid reactive substances (TBARS) values of breast meat were reduced significantly ($P<0.05$) in T_1 group compared to the control treatment. A significant reduction of total cost and increment of net return and benefit cost ratio (BCR) found in treatment groups particularly in T_2 group compared to the control ($P<0.01$). Finally, dietary supplementation of Tamarind tree leaves with dry and fermented leaves improved growth performance, CP, EE, blood HDL cholesterol level and net return, while reduced blood total cholesterol, LDL cholesterol, triglyceride and meat TBARS value. Thus, it can be suggested from this study that Tamarind tree leaves can be supplemented as an effective feed additive for broilers.

Introduction

Poultry plays an important role in reducing the gap of protein supply in the country. Protein is an essential macronutrient of the body. Now-a-days poultry industry has been successfully becoming a leading industry in Bangladesh (Ali and Hossain, 2012). Broiler meat is becoming very popular all over the world for all kind of people due to its better digestibility. The Poultry farming provides economic benefits to the poor farmers. Besides this it also help to improve health of their family. A modernistic challenge in poultry production is to exploit the use of specific dietary supplements to boost the intrinsic potential of poultry birds to perform better (Adil *et al.*, 2010). Probiotics, enzymes, amino acid supplements, available minerals and herbal plants are all relatively new additions to the harmony of poultry nutritionists and have a very positive effect on nutrient utilization when used with appropriate feed ingredients. In the past, nutritionists have used antibiotics to improve performance in the broiler chicken industry (Geidam *et al.*, 2006). But in recent years, the use of antibiotics as feed additives has been banned in most countries of the world because of concerns about the potential increase in antibiotic resistant strains of bacteria and antibiotic residues in poultry products (Windisch *et al.*, 2008). The use of antibiotics as growth-promoting substances in poultry industry is risky because of the development of cross-resistance among pathogens and the harm they cause to humans once they enter the food cycle (Marshall and Levy, 2011). However, this has compromised their immunity and immune response which cannot be improved by use of antibiotics in feed

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due to their inherent ill effects on public health. For these reasons their use as growth promoters is prohibited in many countries (Attia *et al.*, 2011). In these circumstances, it was found necessary to develop alternatives using either beneficial microorganisms or to use non-digestible ingredients that retard microbial growth (Awad *et al.*, 2009). A group of feed additives that have been generating interest in recent times as a replacement for banned antimicrobials in the poultry industry are the phytogenic feed additives (Jacela *et al.*, 2010). These phytogenic feed additives also called phytobiotics or botanicals are usually plant derived compounds that are used to improve productivity of livestock through improved feed intake, improved gut function, antimicrobial activity and anti-oxidative actions (Windisch *et al.*, 2008). Alternative growth promoters from herbal plants and their bioactive compounds are becoming more important because of their antimicrobial effects and digestion-enhancing capacities (Dhama *et al.*, 2015; Attia *et al.*, 2017).

Tamarind or *Tamarindus indica* L. of the Fabaceae family is an important food in the tropics. It is a multipurpose tree of which almost every part finds at least some use (Kumar and Bhattacharya, 2008) either nutritional or medicinal properties. It (*Tamarindus indica* L.) is a tree which is indigenous to tropical Africa where it still grows in wild (El-Siddig *et al.*, 2006). Although tamarind is indigenous to tropical Africa but it has been introduced and naturalized worldwide in over 50 countries. The major production areas are in the Asian countries - India, Bangladesh, Sri Lanka, Thailand and Indonesia (El-Siddig *et al.*, 2006). According to Kumar and Bhattacharya (2008), the tamarind fruit contains about 55% pulp, 34% seeds and 11% shell (pod). Tamarind has been reported to have anti-diabetic (Koyagura *et al.*, 2013), anti-inflammatory, cholesterol lowering (Chowdhury *et al.*, 2005), anti-obesity (Azman *et al.*, 2012), antifungal (Abubakar *et al.*, 2010), antioxidant (Atawodi *et al.*, 2014), antipyretic (Izquierdo *et al.*, 2007) and antimicrobial (Daniyan *et al.*, 2008) properties. In addition, it has appetizing and stimulatory effect in the digestive process (Cabuk *et al.*, 2003). Aengwanich *et al.* (2009) found that polyphenolic compound in the extracts could reduce heat stress in broiler chickens. *T. indica* leaves contains good amount of protein, fiber, fat and different types of vitamins such as B1, B2, B3, Vit. C, β-carotene (El-Siddig *et al.,* 2006) and also flavonoid and polyphenols (Arya, 1999) which have a proven record as antimicrobial activity. In addition, Vit. C acts as anti-oxidant while β-carotene function as sources of vitamin A (Ames *et al.,* 1993). Now a day's consumers are becoming more health conscious.

Hence, this study was designed to evaluate the effects of *Tamarindus indica* L. leaves on growth performance, meat quality, oxidative stability of meat and economics in broiler rearing.

Materials and Methods

Study area and experimental birds

The experiment was done at Chattogram Veterinary and Animal Sciences University (CVASU) experimental shed. The day-old unsexed broiler chicks of Ross 308 were purchased from Nahar Agro Complex Limited, Chattogram, Bangladesh. All the chicks were examined for abnormalities and uniform size. Average body weight of the chicks was tried to keep similar (about 40.74±0.26 g).

Preparation of Tamarindus indica L. leaves probiotics

After collection of leaves, they were dried, grinded and sterilized after ensuring that the moisture was 30%. Electrical grinder was used to perform the grinding by 3-12 µm particle size. The strains of probiotics purchased from Korea (KCTC, Korean collection for type cultures) for the fermentation process with grinded leaves were selected as *Lactobacillus plantarum* KCTC 3099 and *Saccharomyces cerevisiae* KCTC 7928 based on their acid, bile and salt tolerance levels according to Hossain *et al.* (2012). MRS broth used for growth of *L. plantarum* and YM broth for *S. cerevisiae*. A total of 30% dried ground leaves was mixed with 35% defatted rice bran (DFRB) and 35% distiller's dried grains with soluble (DDGS). A two steps fermentation process was applied to prepare the tamarind leaf probiotics using a laboratory incubator (LGI-150T, Labnics, USA). In the first inoculation, 1% of *L. plantarum* KCTC 3099 was added to solid media and made it moisture content about 40% to make the fermentation process properly by adding adequate distilled water. The mixture was then fermented at 40°C for 2 days under repeating cycles of 5 h of anaerobic and 3 h of aerobic conditions. The second fermentation was performed by adding 1.0% of *S. cerevisiae* KCTC 7904 strains and similarly fermented for 2 days at 40°C under aerobic conditions. The formulated probiotics mixtures were then dried for 2 days until the moisture level was less than 15% using a dry oven (Labnic, USA). To determine the number of cells, 1g of tamarind leaf probiotics was 10-fold serially diluted with sterilized saline solution (0.85% NaCl) at room temperature and cultured in solid media. The culture plate was then incubated at 37°C for 24–48 h, after which the number of colonies was counted by colony counter and expressed as *L. plantarum* KCTC 3099 2.2×10^7 and *S. cerevisiae* KCTC 7928 was 2.6×10^8 cfu/ml.

Design of experiment

A total of 90 birds were randomly distributed into three dietary treatment groups: T_0 = Control (basal diet), T_1 = (basal diet + 0.4% dried tamarind leaves on DM basis)

and T_2 = (basal diet + 0.4% fermented tamarind leaves on DM basis) consists of 3 replications having 10 birds per replicates in a completely randomized design. Total experiment was divided into 2 periods. First 2 weeks were the adjustment periods and next 2 weeks were the treatment periods. Birds were kept during adjustment period due to some adverse environmental issues. In the beginning of the experiment, the weather was extreme hot and the birds were dehydrated. Besides this, the weather was frequently changed and tamarind is very new as feed additives in our country. So, birds were provided basal diet for the first 2 weeks for adjustment and after 2 weeks, treatment diet started to provide.

Experimental diets

A commercial maize and soybean meal-based diet used as the basal diet to meet the nutrient requirements of specific broiler chickens. The starter diets were offered from day 1 to day 14, while grower diets were provided from day 15 to day 28. The experimental diet (dried and fermented tamarind leaves) was provided from day 15 to day 28 due to some adverse environmental issues. The proximate composition of experimental basal diet (Starter and Grower) were determined by the method described by the Association of Official Analytical Chemists (AOAC, 2000) and shown in Table 1.

Management

Standard management procedure (NRC, 1994) was tried to maintain for the entire experimental periods. Poultry shed was prepared for broiler rearing. Birds were kept in a close ventilated, wire-floor caged broiler house (3.5 ft. × 1.63 ft. for 10 birds). Therefore, floor space for each bird in the cage was 0.57 sq. ft. respectively. The cages had a round feeder and drinker to provide feed *ad libitum* and free access to water. All birds were vaccinated properly against against Newcastle disease on the 4th and 17th day and Infectious Bursal Disease on 12th day.

Laboratory works

Carcass characteristics

At the end of the 28 day of experiment period, two birds were randomly selected from each replicate and slaughtered by severing the jugular vein and carotid artery. The birds were segregate as per the technique described by Jones (1984). During evisceration process, abdominal fat, liver, spleen, bursa, gizzard were excised separately and weighed. Dressed birds were weighed to obtain a dressed carcass weight. Total breast meat, thigh meat and thigh bone weight were recorded.

Proximate analysis of meat

After separating and weighing of different organ, the breast meat samples were collected for proximate composition and oxidative stability analyses. Equal portions of breast meat were ground in a meat grinder and stored at −20°C until analysis. Chemical analyses of the meat samples were carried out in triplicate for dry matter (DM), crude protein (CP, 990.03), ether extract (EE, 991.36) and total ash (TA, 942.05) in Animal Nutrition and Post Graduate laboratory under the department of Animal Science and Nutrition, CVASU as described by AOAC (2000).

Biochemical analysis

Blood samples were collected from the brachial vein of two birds from each replication using a 5 ml sterile syringe and a 23-gauge needle. From each bird, 5 ml blood sample was transferred immediately into a sterile tube without anticoagulant. Clotted blood in the vacutainer tube was centrifuged at 3000 rpm for 20 minutes and prepared serum was collected into the eppendorf tube by micropipette. Different blood parameters (cholesterol; triglyceride; low density lipoprotein, LDL and high density lipoprotein, HDL) were measured in the post graduate laboratory under the department of Animal Science and Nutrition, CVASU using standard kits (BioMereux, France) and automatic analyzer (Humalyzer 300, Merck®, Germany) according to the manufacturer's instruction.

Oxidative stability of meat

For determination of the oxidative stability of broiler breast meat samples were preserved in a refrigerator at 4°C and thiobarbituric acid reactive substances (TBARS) values of meat were assayed when fresh as well as at 1st, 2nd and 3rd week according to the method of Sarker and Yang (2011). TBARS values are expressed as micromoles of malondialdehyde (MDA) per 100g of meat sample. Briefly, 4g of each sample were mixed with 10 ml of a solution containing 20% trichloroacetic acid (TCA) in 2 M phosphoric acid and 10 ml of distilled water. The mixture was then diluted and homogenized properly with a homogenizer and filtered through Whatman No. 1 filter paper. After filtering, 2 ml of the filtrate were transferred to a test tube and 2 ml of 2-thiobarbituric acid (0.005 M in DW) was added. The sample test tube was then kept in the hot water bath at 80°C for 30 minutes. After 30 minutes, test tubes were removed from the water bath and kept at room temperature. The absorbance was than measured by using a Spectrophotometer (Model 20D+, Milton Roy, Warminster, PA, USA) at 530 nm.

Statistical analysis

All the data were entered into MS excel (Microsoft office excel-2010, USA) and analyzed by using the General Linear Model (GLM) procedure of SAS Institute Inc. (2003). Duncan's multiple range tests were used to examine significant differences among the treatment means. All data was expressed as SEM. The level of statistical significance was presented at $P<0.05$.

Results and Discussion

Average daily gain (ADG)

Growth performance of broilers of this study is represented in Table 2. Results indicated that, increased ADG was observed in T_1 and T_2 group and decreased in control group during 3rd and 4th week ($P<0.05$). Overall ADG also increased in treatment groups significantly compared to control (Table 2). Shinde *et al.* (2015) showed quite relevance with this information where they applied 0.25%, 0.50% and 1.0% dried tamarind pulp powder (DTPP) in broiler diet. In another study, Saleh *et al.* (2012) observed the influence of an aqueous solution of tamarind pulp on growth of broiler where body weight gain was significantly increased ($P<0.05$). It could have been due to its appetizing and stimulatory effect in the digestive process (Cabuk *et al.*, 2003). In addition, improved weight gain might be due to the synergistic effect of probiotics which enhance the digestive enzyme action, addition of beneficial microbes in the gut that can accelerate digestion and nutrient utilization (Tellez *et al*., 2001; Chen *et al.*, 2013). Similar finding also reported by Adejumo *et al.* (2004) and Nawaz *et al.* (2016).

Average daily feed intake (ADFI)

Average daily feed intake (ADFI) of this study remained unchanged in all treatment groups in comparison with control (Table 2). Aengwanich *et al.* (2009) found and reported the quite relevance with this present study where they found feed intake of broilers in all groups were non-significant ($P>0.05$). This could be due to the absent any harmful matter which could reduce feed intake.

Feed conversion ratio (FCR)

The feed conversion ratio shows a significant reduction in all dietary supplemented groups compared to control where the lowest FCR value was obtained in fermented tamarind leaf supplement that can be explained by improved protein digestion for using probiotics (Table 2). Saleh *et al.* (2012) found that, supplementation of broiler diets with aqueous solution of tamarind pulp improved FCR significantly. Shinde *et al.* (2015) showed that, supplementation of broiler diets with dried tamarind pulp powder with various inclusion levels improved FCR as compared with birds in control group. Balaji *et al.* (2013) reported that, supplementation of decorticated tamarind seed meal at 5% significantly improved FCR.

Serum biochemical parameters

Different blood serum parameters estimated have been presented in Table 3. The blood cholesterol and triglyceride (TG) level reduced dramatically in all treatment groups than control ($P<0.0001$). HDL value was found higher in T_2 group and lower in T_1 and control group ($P<0.0009$). In case of LDL, T_1 and T_2 both group shows the lower average value compared with control group ($P<0.0001$). According to Rafiq *et al.* (2016), phenolic compounds control the accumulation of cholesterol esters and citrus tree leaves are a rich source of phenolic compounds. Lowest level of triglyceride was found in fermented leaves treated group and higher in control group. It might be due to synergistic effects of probiotics and plant phytochemicals. A study by Martinello *et al.* (2006) reported that 50% reduction in total serum cholesterol, HDL, LDL and triglyceride level after supplementation of tamarind fruit pulp extract (5%) in hamster. Similar observations were also reported by Iftekhar *et al.* (2006) in humans, Jindal *et al.* (2011) in rats and Shinde *et al.* (2015) in broilers after supplementation of tamarind pulp extract at different levels.

Chemical composition of meat

Dietary effects of tamarind leaves in proximate composition of meat are represented in Table 4. Results showed a significant difference in crude protein (CP) and ether extract (EE) in comparison with control ($P<0.005$). T_2 treatment group showed the highest value of CP and EE While lower CP and EE values were obtained in control and T_1 group, respectively. However, dry matter (DM) and ash did not differ significantly ($P>0.05$). There were no marked changes in the chemical composition of meat in terms of dry matter (DM) and ash. Combined effect of probiotics and tamarind leaf's bioactive compound enhance the digestion and absorption of gut nutrients. Anjum *et al.* (2005) reported no significant differences in meat composition among all the diets with the supplement of probiotics. To the best of our knowledge, no other studies are available for comparison.

Carcass characteristics

Different carcass characteristics presented in Table 5. Results showed that relative breast meat weight and heart weight were increased markedly ($P<0.05$) while abdominal fat was reduced in treatment group than control. Although other collected parts of carcass had no significant difference compared to the control. According to Shinde *et al.* (2015), abdominal fat, carcass yield, dressing percentage were significantly lower with dried tamarind pulp powder supplement. In another study, Balaji *et al.* (2013) was observed no significant difference in weights of organs in the different treatment groups. Saleh *et al.* (2012) showed that, there were no significant differences observed for slaughter weight, dressed weight and dressing percentage but tamarind pulp had significant influence on all cut-up parts.

Oxidative stability of meat

The effects of tamarind leaves in TBARS value of breast meat of broiler kept at 4°C for 3 weeks are shown in Table 6. No significant difference was observed in fresh meat sample. But a significant reduction was observed in first to third weeks in T_1 group ($P<0.05$). Similarly Devatkal *et al.* (2010) reported a significant ($P<0.5$) reduction in average TBARS values (lipid oxidation) with citrus peel as compared to the control. The causes of reduction of TBARS value are due to the effects of citrus tree by-products that contain phenolic compounds that scavenge free radicals (Devatkal *et al.*, 2010). El-Siddig *et al.* (2006) reported that T. indica leaves contains good amount of protein, fiber, fat and different types of vitamins such as B1, B2, B3, Vit. C, β-carotene and also flavonoid and polyphenols (Arya, 1999) which can acts as anti-oxidant whereas β-carotene function as a sources of vitamin A (Ames *et al.*, 1993). Moreover, compounds such as flavonoids and terpenoids also have antioxidant properties (Rizzo *et al.*, 2008) and probiotics that also act as antioxidant (Wang *et al.*, 2017).

Table 1. Ingredients and chemical composition of experimental basal diet.

Ingredients (as % feed basis)	Starter (0-14 days)	Grower (15-28 days)
Corn	52.00	53.00
Wheat	2.00	2.00
Rice polish	2.50	3.20
Soybean meal	32.00	29.20
Fishmeal	4.00	3.50
Palm oil	3.50	5.00
DCP	1.79	1.79
Limestone	1.15	1.15
NaCl	0.30	0.30
Choline chloride	0.06	0.06
Vitamin min premix[1]	0.15	0.15
L-lysine	0.40	0.40
DL-methionine	0.22	0.22
Toxin binder	0.25	0.25
Enzymes	0.04	0.04
Chemical composition (as fed basis)		
ME (kcal/kg)	3001.65	3104.85
Crude protein %	22.09	20.71
Crude fiber %	3.76	3.68
Ether extract %	3.67	3.68
Lysine %	0.72	0.80
Calcium %	1.30	1.26
Phosphorus %	0.72	0.70

[1]Vitamin-mineral mixture provided the following nutrients per kg of diet: Vitamin A 15,000 IU, Vitamin D3 1500 IU, Vitamin E 20.0mg, Vitamin K3 0.70 mg, Vitamin B12 0.02 mg, Niacin 22.5 mg, thiamin 5.0 mg, folic acid 0.70 mg, pyridoxine 1.3 mg, riboflavin 5 mg, pantothenic acid 25 mg, choline chloride 175 mg, Mn 60 mg, Zn 45mg, I 1.25 mg, Se 0.4 mg, Cu 10.0 mg, Fe 72 mg, Co 2.5 mg.

Table 2. Dietary effect of tamarind leaves on growth performance of broiler

Parameters	Treatments			SEM	Pvalue
	T_0	T_1	T_2		
3rd week					
ADG (g/b/d)	65.37[b]	66.55[a]	67.14[a]	0.31	0.03
ADFI (g/b/d)	75.63	73.24	75.46	0.61	0.06
FCR	1.16[a]	1.10[c]	1.13[b]	0.01	0.002
4th week					
ADG (g/b/d)	85.12[c]	87.07[b]	91.77[a]	0.36	<.0001
ADFI (g/b/d)	108.29	106.34	109.38	2.77	0.80
FCR	1.27[a]	1.22[b]	1.19[b]	0.01	0.005
Overall (15-28 days)					
ADG (g/b/d)	75.25[c]	76.81[b]	79.46[a]	0.08	<.0001
ADFI (g/b/d)	91.96	89.79	92.42	1.32	0.44
FCR	1.22[a]	1.17[b]	1.16[b]	0.01	0.008

[a,b,c] Means in a row with no common superscripts significantly differ ($P<0.05$); Data presented as the mean value of 3 replicate groups with 10 birds per replication (n=30); T_0 = Control; T_1 = 0.4% dry tamarind leaf; T_2 = 0.4% fermented tamarind leaf; ADG = Average daily gain; ADFI = Average daily feed intake; FCR= Feed conversion ratio;
SEM = Standard error of mean.

Table 3. Dietary effect of tamarind leaves supplementation on blood serum parameters in broiler

Parameters	Treatments			SEM	P value
	T_0	T_1	T_2		
Cholesterol (mg/dl)	126.73[a]	78.43[c]	101.38[b]	1.40	<.0001
TG (mg/dl)	86.68[a]	43.87[b]	35.30[c]	2.21	<.0001
HDL (mg/dl)	76.92[b]	63.61[c]	84.34[a]	1.82	0.0009
LDL (mg/dl)	32.48[a]	6.05[b]	9.98[b]	1.81	0.0001

[a,b,c] Means in a row with no common superscripts significantly differ (P<0.05); Data presented as the mean value of 3 replicate groups with 3 birds per replication (n=9); T_0 = Control; T_1 = 0.4% dry tamarind leaf; T_2 = 0.4% fermented tamarind leaf; SEM = Standard error of mean.

Table 4. Dietary effect of tamarind leaves on meat proximate composition

Parameters (%)	Treatments			SEM	P value
	T_0	T_1	T_2		
DM	87.25	86.50	85.04	0.78	0.26
CP	22.17b	22.69b	23.94a	0.20	0.003
EE	1.60b	1.45c	1.69a	0.02	0.001
Ash	0.98	0.93	0.89	0.04	0.49

[a,b,c] Means in a row with no common superscripts significantly differ (P<0.05); Data presented as the mean value of 3 replicate groups with 3 birds per replication (n=9); T_0 = Control; T_1 = 0.4% dry tamarind leaf; T_2 = 0.4% fermented tamarind leaf; SEM = Standard error of mean.

Table 5. Dietary effect of tamarind leaves on carcass characteristics and organ weight of broiler

Parameters (% in relation to body weight)	Treatments			SEM	P value
	T_0	T_1	T_2		
Dressed wt	61.35	61.46	58.44	0.97	0.13
Relative breast meat wt	16.05[b]	18.80[a]	17.29[ab]	0.48	0.03
Thigh meat (with bone)	17.46	18.18	16.95	0.41	0.19
Thigh meat wt	14.17	16.03	15.33	0.63	0.19
Thigh bone wt	3.30	3.28	3.49	0.26	0.84
Liver	2.35	2.52	2.49	0.23	0.89
Gizzard	1.70	2.03	2.05	0.35	0.75
Heart	0.54[b]	0.59[ab]	0.68[a]	0.03	0.03
Spleen	0.09	0.09	0.09	0.01	0.98
Bursa	0.19	0.20	0.17	0.01	0.22
Abdominal fat	0.67[a]	0.59[b]	0.54[c]	0.01	0.003

[a,b,c] Means in a row with no common superscripts significantly differ (P<0.05); Data presented as the mean value of 3 replicate groups with 3 birds per replication (n=9); T_0 = Control; T_1 = 0.4% dry tamarind leaf; T_2 = 0.4% fermented tamarind leaf; SEM = Standard error of mean.

Table 6. Dietary effect of tamarind leaves on meat thiobarbituric acid reactive substances (TBARS) value of broiler meat (µmol of MDA/100g meat)

Period	Treatments			SEM	P value
	T_0	T_1	T_2		
Fresh	2.35	2.98	2.33	0.50	0.61
1st week	3.53b	3.05b	4.93a	0.35	0.02
2nd week	25.70a	18.63b	29.98a	1.20	0.002
3rd week	35.08b	32.38b	43.23a	0.94	0.001
Average	16.67ab	14.26b	20.11a	1.13	0.03

[a,b,c] Means in a row with no common superscripts significantly differ (P<0.05); Data presented as the mean value of 3 replicate groups with 3 birds per replication (n=9); T_0 = Control; T_1 = 0.4% dry tamarind leaf; T_2 = 0.4% fermented tamarind leaf; SEM = Standard error of mean; MDA = Malondialdehyde

Table 7. Cost-benefit analysis of broiler fed diets supplemented with tamarind leaves

Parameters	Treatments			SEM	P value
	T_0	T_1	T_2		
Total fixed cost (Housing, equipment etc., BDT/bird)	7.00	7.00	7.00	0.00	NS
Total variable cost (Chick, feed, labour, vaccine, electricity, miscellaneous, interest on operating capital etc., BDT/bird)	116.61[a]	114.55[b]	114.28[b]	0.21	0.0004
Total return (Bird sale, BDT/bird)	166.25[b]	168.33[b]	173.75[a]	1.22	0.01
Total cost (BDT/bird)	123.61[a]	121.55[b]	121.28[b]	0.21	0.0004
Net return (BDT/bird)	42.64[b]	46.78[b]	52.47[a]	1.32	0.0078
BCR	1.34[b]	1.38[b]	1.43[a]	0.01	0.0062

[a,b,c] Means in a row with no common superscripts significantly differ (P<0.05); Data presented as the mean value of 3 replicate groups with 10 birds per replication (n=30); T_0 = Control; T_1 = 0.4% dry tamarind leaf; T_2 = 0.4% fermented tamarind leaf; SEM = Standard error of mean. BCR = Benefit cost ratio

Cost-benefit analysis

Economics of broiler rearing of this study is represented in Table 7. A significant reduction (P<0.01) of total cost was observed in T1 and T2 group than the control group (T0) (Table 7). Total return, net return and BCR was found higher in treatment group than the control group (P<0.01).

Conclusion

The study investigated the dietary effects of dry and fermented tamarind leaves supplementation on growth performance, carcass characteristics, biochemical parameters, oxidative stability and economic appraisal of broiler rearing. It was evident that, there was a positive relationship between tamarind leaves supplementation and growth performance of commercial broiler. Highest weekly ADG and overall (14 to 28 days) and better FCR were observed in birds fed diet containing fermented leaves than control. Dry leaves treated group also showed better result compared to the control. The blood cholesterol, triglyceride and LDL level reduced significantly and HDL level increased in treatment groups in comparison with control group. In case of chemical composition of meat, there was a significant increase in CP and EE content in treatment groups than control. Carcass characteristics were improved in terms of breast muscles yield in tamarind leaves treated group. A significant reduction of TBARS value was observed in dry leaves treated groups compared to control. The study, therefore, suggests that, both dry and fermented tamarind leaf may be a potential feed supplement with basal diet. Besides this, fermented leaves could be very effective on the basis of growth performance. However, a long term investigation with larger sample size and multi-dimensional temporal pattern is suggested for increasing sensitivity and validity of the study under field condition.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Abubakar, M.G., Yerima, M.B., Zahriya, A.G. and Ukwuani, A.N. 2010. Acute toxicity and antifungal studies of ethanolic leaves, stem and pulp extract of *Tamarindus indica*. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 1(4): 104-111. http://rjpbcs.com/pdf/2010_1(4)/[11].pdf

Adejumo, D.O., Onifade, A.A. and Afonja, S. A. 2004. Supplemental effects of dried yeast (Yea-sacc 1026 P®) in a low protein diet on growth performance, carcass characteristics and organ weights of broiler chicken. *Tropical Veterinarian,* 22(2): 72-77. https://www.ajol.info//index.php/tv/article/view/4555

Adil, S., Banday, T., Bhat, G.A., Mir, M.S. and Rehman, M. 2010. Effect of dietary supplementation of organic acids on performance, intestinal histomorphology and serum biochemistry of broiler chicken. *Veterinary Medicine International*, https://www.hindawi.com/journals/vmi/2010/479485/

Aengwanich, W., Suttajit, M., Srikhun, T. and Boonsorn, T. 2009. Antibiotic effect of polyphenolic compound extracted from tamarind (*Tamarindus indica* L.) seed coat on productive performance of broilers. *International Journal of Poultry Science*, 8(8):749-751. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.483.3074&rep=rep1&type=pdf

Ali, M.M. and Hossain, M.M. 2012. Problems and prospects of poultry industry in Bangladesh: an analysis. Dhaka: *Americal Internation University Bangladesh* (AIUB) *Bus Econ working paper series*, 1-18. https://bea-bd.org/site/images/pdf/15.pdf

Ames, B.N., Shigenaga, M.K. and Hagen, T.M. 1993. Oxidants, antioxidants, and the degenerative diseases of aging. *Proceedings of the National Academy of Sciences of the United States of America*, 90(17): 7915–7922. https://doi.org/10.1073/pnas.90.17.7915

Anjum, M.I., Khan, A.G., Azim, A. and Afzal, M. 2005. Effect of dietary supplementation of multi-strain probiotic on broiler growth performance. *Pakistan Veterinary Journal*, 25(1): 25-29. https://pdfs.semanticscholar.org/81cf/c144ab24dacebd84003c97def34dd8d2d738.pdf

NRC. 2008. Tamarind, in Lost Crops of Africa: Volume III: Fruits. The National Academies Press Washington DC, 148–63. https://infonet-biovision.org/sites/default/files/lost_crops_of_africa_vol_3_fruits.pdf

AOAC. 2000. Official methods of analysis of AOAC. International 17th edition; Gaithersburg, MD, USA Association of Analytical Communities.

Atawodi, S.E., Liman, M.K.L., Ottu, J.O. and Iliemene, U.D. 2014. Total polyphenols, flavonoids and antioxidant properties of different parts of *Tamarindus indica* Linn of Nigerian origin. *Annual Research and Review in Biology*, 4(24): 4273-4283. https://doi.org/10.9734/ARRB/2014/8602

Attia, Y.A., Al-Harthi, M.A. and Hassan, S.S. 2017. Turmeric *(Curcuma longa* Linn.*)* as a phytogenic growth promoter alternative for antibiotic and comparable to mannan oligosaccharides for broiler chicks. *Revista Mexicana de Ciencias Pecuarias*, 8:11-21. http://www.scielo.org.mx/scielo.php?pid=S2007-11242017000100011&script=sci_arttext&tlng=en

Attia, Y.A., Zeweil, H.S., Al-saffar, A.A. and El-Shafy, A.S. 2011. Effect of non-antibiotic feed additives as an alternative to flavomycin on broiler chickens production. *Archiv fur Geflugelkunde*, 75: 40-48.

Awad, W.A., Ghareeb, K., Abdel-Raheem, S. and Böhm, J. 2009. Effects of dietary inclusion of probiotic and synbiotic on growth performance, organ weights, and intestinal histomorphology of broiler chickens. *Poultry Science*, 88: 49–56. https://doi.org/10.3382/ps.2008-00244

Azman, K.F, Amom, Z., Azlan, A., Esa, N.M., Ali, R.M., Shah, Z.M. and Kadir, K.K.A. 2012. Antiobesity effect of *Tamarindus indica* L. pulp aqueous extract in high-fat diet-induced obese rats. *Journal of National Medicine*, 66(2):333-342. https://doi.org/10.1007/s11418-011-0597-8

Balaji, M., Chandrasekaran, D., Ravi, R., Purushothaman, M.R. and Pandiyan,V. 2013. Feeding value of decorticated tamarind seed meal for broilers. *Indian Journal of Poultry Science*, 48(1): 37-41. http://www.indianjournals.com/ijor.aspx?target=ijor:ijps&volume=48&issue=1&article=008

Cabuk, M., Alcicek, A., Bozkurt, M. and Imer, N. 2003. Antimicrobial properties of the essential oils isolated from aromatic plants and using possibility as alternative feed additives. II National

Animal Nutrition Congress, Antalya, Turkey: 184-187.

Chen, W., Wang, J.P., Yan, L. and Huang, Y. Q. 2013. Evaluation of probiotics in diets with different nutrient densities on growth performance, blood characteristics, relative organ weight and breast meat characteristics in broilers. *British Poultry Science*, 54(5): 635-641. https://www.ncbi.nlm.nih.gov/pubmed/24112072

Chowdhury, S.R., Sarker, D.K., Chowdhury, S.D., Smith, T.K. and Roy, P.K. 2005. Effects of dietary tamarind on cholesterol metabolism in laying hens. *Poultry Science*, 84: 56–60. https://doi.org/10.1093/ps/84.1.56

Daniyan, S.Y. and Muhammad, H.B. 2008. Evaluation of the antimicrobial activities and phytochemical properties of extracts of *Tamaridus indica* against some diseases causing bacteria. *African Journal of Biotechnology*, 7 (14): 2451-2453. https://www.ajol.info/index.php/ajb/article/view/59019

Devatkal, S.K, Narsaiah, K. and Borah, A. 2010. Anti-oxidant effect of extracts of kinnow rind, pomegranate rind and seed powders in cooked goat meat patties. *Meat Science*, 85(1): 155-159. https://doi.org/10.1016/j.meatsci.2009.12.019

Dhama, K., Latheef, S.K., Mani, S., Samad, H.A., Karthik, K., Tiwari, R., Khan, R.U., Alagawany, M., Farag, M.R., Alam, G.M., Laudadio, V. and Tufarelli, V. 2015. Multiple beneficial applications and modes of action of herbs in poultry health and production – A review. *International Journal of Pharmacology*, 11:152-176. https://scialert.net/abstract/?doi=ijp.2015.152.176

El-Siddig, K., Gunasena, H.P.M., Prasa, B.A., Pushpakumara, D.K., Ramana, N.G., Vijayanand, P. and Williams, J.T. 2006. Tamarind –*Tamarindus indica* L. fruits for the future. Southampton Centre for Underutilized Crops, Southampton, UK. P: 188.

Geidam, Y.A., Bukar, M.M. and Ambali, A.G. 2006. Chick quality control: a key to sustainable poultry production in Nigeria. *Nigerian Veterinary Journal*, 27(2): 1-6. https://www.ajol.info/index.php/nvj/article/view/3509

Hossain, M.E., Ko, S.Y., Kim, G.M., Firman, J.D. and Yang, C.J. 2012. Evaluation of probiotic strains for development of fermented *Alisma canaliculatum* and their effects on broiler chickens. *Poultry Science*, 91(12): 3121-3131. https://doi.org/10.3382/ps.2012-02333

Iftekhar, A.S., Rayhan, I., Quadir, M.A., Akhteruzzaman, S. and Hasnat, A. 2006. Effect of *Tamarindus indica* fruits on blood pressure and lipid-profile in human model: an in vivo approach. *Pakistan Journal of Pharmacology Science*,19(2):125-129.

Izquierdo, T., GraciaTamayo, F., Soto, C. and Castrillon, L.E. 2007. A *Tamarindus indica* Linn pulp polysaccharide inhibits fever in-vivo and IL-1β release by murine peritoneal exudate cell. *Pharmaceutical Biology*, 45:22-30. https://doi.org/10.1080/13880200601026309

Jacela, J.Y., DeRouchey, J.M., Tokach, M.D., Goodband, R.D., Nelssen, J.L., Renter, D.G. and Dritz, S.S. 2010. Feed additives for swine: Fact sheets- probiotics and probiotics, and pytogenics. *Journal of Swine Health and Production*, 18(3): 132-136. https://www.aasv.org/shap/issues/v18n3/v18n3p132.pdf

Jindal, V., Dhingra, D., Sharma, S., Parle, M. and Harna, R. 2011. Hypolipidemic and weight reducing activity of the ethanolic extract of *Tamarindus indica* fruit pulp in cafeteria diet and sulpiride induced obese rats. *Journal of Pharmacology Pharmacother*, 2(2): 80–84. 10.4103/0976-500X.81896

Jones, R. 1984. A standard method of dissection for carcass analysis of poultry. Ayr, Scotlands: West of Scotland Agricultural Research. Technical Note No.: 222.

Koyagura, N., Kumar, V.H., Jamadar, M.G., Huilgol, S.V., Nayak, N., Yendigeri, S.M. and Shamsuddin, M. 2013. Antidiabetic and hepatoprotective activities of *Tamarindus indica* fruit pulp in alloxan induced diabetic rats. International *Journal of Pharmacology and Clinical Sciences*, 2(2): 33-40. https://www.ijphs.org/article/2013/2/2

Kumar, C.S. and Bhattacharya, S. 2008. Tamarind Seed: Properties, Processing and Utilization. *Critical Reviews in Food Science and Nutrition*, 48: 1-20. https://doi.org/10.1080/10408390600948600

Marshall, B.M. and Levy, S.B. 2011. Food animals and antimicrobials: impacts on human health. *Clinical Microbiology Reviews*, 24:718-733. https://cmr.asm.org/content/24/4/718.full

Martinello, F., Soares, S.M., Franco, J.J., Santos, A.C., Sugohara, S.B., Garcia, C. and Curti, S.A. 2006. Hypolipemic and antioxidant activities from *Tamarindus indica* L. pulp fruit extract in hypercholesterolemic hamsters. *Food Chemistry and Toxicology*, 44(6):810-818. https://doi.org/10.1016/j.fct.2005.10.011

National Research Council. 1994. Nutrients Requirements of Poultry. 8th edn. Washington, DC, National Academy Press,USA.

Nawaz, H., Irshad, M.A., Mubarak, A. and Ahsan-Ul-Haq. 2016. Effect of probiotics on growth performance, nutrient digestibility and carcass characteristics in broilers. *The Journal of Animal and Plant Sciences*, 26(3): 599-604.

Rafiq, S., Kaul, R., Sofi, S.A., Bashir, N., Nazir, F. and Nayik, G.A. 2016. Citrus peel as a source of functional ingredient: a review. *Journal of the Saudi Society of Agricultural Sciences*. https://core.ac.uk/download/pdf/81971257.pdf

Rizzo, P.V., Menten, J.F.M., Racanicci, A.M.C. and Santarosa, J. 2008. Foundation and perspectives of the use of plant extracts as performance enhancers in broilers. *Brazilian Journal of Poultry Science*, 10:195-204. https://doi.org/10.1590/S1516-635X2008000400001

Saleh, B., Duwa, H., Diarra, S.S., Vandi, T.J. and Abdullahi, H.A. 2012. Influence of tamarind pulp on growth and carcass characteristics of broiler chickens. *Research Opinions in Animal and Veterinary Sciences*, 2 (10): 511-514. http://repository.usp.ac.fj/5743/

Sarker, M.S.K and Yang, C.J. 2011. Eosungcho (*Houttuynia cordata*) with multi strain probiotics as alternative to antibiotic for broiler production. *Journal of Medicinal Plant Research*, 5:4411-4417. https://www.cabdirect.org/cabdirect/abstract/20113327323

SAS. 2003. SAS User's Guide. 9.1 Edition, SAS Institute Inc., Cary, North Carolina, USA.

Shinde, G. B., Kanduri, A.B., Deshmukh, G.B., Gaikwad, N.Z., Khan, M.A. and Pawar, P.H. 2015. Utilization of tamarind (*Tamarindus indica* L.) pulp as feed supplement in broiler chicken. *Maharashtra Animal and Fishery sciences university*, Nagpur.

Tellez, G., Petrone, V.M., Excorcia, M., Morishita, T.Y., Cobb, C.W. and Villasenor, L. 2001. Evaluation of avian-specific probiotics and *Salmonella* enteritidis, *Salmonella* typhimurium, and *Salmonella* Heidelberg specific antibodies on cecal colonization and organ invasion of *Salmonella* enteritidis in broilers. *Journal of Food Production*, 64(3): 287-291. https://doi.org/10.4315/0362-028X-64.3.287

Wang, Y., Wu, Y., Xu, H., Mei, X., Yu, D. and Li, W. 2017. Antioxidant properties of probiotic bacteria. *Nutrients*, 9(5): 521. https://doi.org/10.3390/nu9050521

Windisch, W., Schedle, K., Plitzner, C. and Kroismayr, A. 2008. Use of phytogenic products as feed additives for swine and poultry. *Journal of Animal Science*, 86(14): E140-E148. https://doi.org/10.2527/jas.2007-0459