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Original Article

Evaluating the Effects of Dried Orange and Lemon Peel on Growth Performance and Meat Quality of Broilers

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ABSTRACT

The study's goal was to assess the effects of dietary inclusion of dried orange peel (DOP) and dried lemon peel (DLP) on broiler growth performance and meat quality. Five dietary treatments namely basal diet (control); basal diet plus 0.5% DOP; basal diet plus 0.5% DLP; basal diet plus 1.0% DOP and basal diet plus 1.0% DLP were given to 200 one-day-old broiler chicks for 35 days. The results showed that dietary supplementation with 0.5% DLP, 1.0% DOP, and 1.0% DLP significantly increased broiler body weight gain and feed conversion ratio in comparison to the control and 0.5% DOP supplemented groups ($P<0.05$). The dressing percentage in all supplemented groups was significantly greater, while proportion of breast meat was higher in the 0.5% DLP, 1.0% DOP, and 1.0% DLP supplemented groups ($P<0.05$). The relative weight of the spleen was significantly higher and that of abdominal fat was lower in the 0.5% and 1.0% DLP supplemented groups ($P<0.05$). The control group had the highest net profit per broiler followed by the 1.0 % DLP supplemented group. As a conclusion, DOP and DLP can be employed as possible feed additives in broiler diet at a concentration of up to 1% to improve broiler growth performance, meat yield without affecting the profitability.

Introduction

Since the early 1990s, commercial poultry production in Bangladesh has grown significantly due to improved genetics, manufactured diets, and management. This industry is one of Bangladesh's most promising industries, with the potential to raise GDP growth rates while also assuring food security, producing purchasing power, and decreasing poverty through the production of meat and eggs (Islam *et al*., 2014). Poultry meat is the most often consumed protein in Bangladesh due to its low cost and accessibility. According to Begum *et al*. (2011), poultry meat accounts for 37% of overall meat output and 22-27% of total animal protein supply in Bangladesh. However, antibiotics are used inappropriately by farmers to control and treat various diseases as well as boost the broiler's performance, resulting in bacterial resistance and antibiotic dregs in animal products (Gaskins *et al*., 2002; Saiful *et al*., 2016). This resulted in prohibition of the use of antibiotics as veterinary medicines and growth promoters (Dabagh *et al*., 2017). This issue encouraged researchers and producers to look for feed alternatives that would accelerate the growth of modern broilers while also improving the meat's nutritional composition in a safe and cost-effective manner.

Citrus fruits are one of the most widely grown fruit crops in the world, and they contain significant phytochemicals (Hou *et al*., 2019; Satari and Karimi, 2018). The peels of citrus fruit make up about 40–50% of the total fruit mass (Singh *et al*., 2020), and it's collected after the juice has been extracted and the pulp within has been removed. These are generally referred to as agro-industrial wastes (Negro *et al*., 2016), which can otherwise be used as animal feed but become a source of environmental problems due to fermentation and microbial decomposition processes (Casquete *et al*., 2015; Satari and Karimi, 2018).

Oranges account for the majority of citrus production worldwide, followed by mandarins (Satari and Karimi, 2018). Orange peel is rich in pectin, cellulose, and hemicellulose, which also contains 5.8% protein (Bampidis *et al*., 2006) and flavonoids (3.68 mg quercetin/gram) linked to antioxidant action (Kanaze *et al*., 2008). The essential oils

of *Citrus sinensis* peels have antibacterial, insecticidal, and disinfectant properties (Parmar and Kar, 2007; Prabuseenivasan *et al*., 2006). After orange and mandarin, lemon (*Citrus limon*) is the third most important citrus species. Lemon peel can be as a potential livestock feed because it contains a potential amount of protein (9.42%), fat (4.98%), ash (6.26%), fiber (15.18%), and important minerals such as sodium, potassium, calcium, copper, iron, magnesium, zinc, and phosphorus, all of which are comparable to other livestock feeds (Janati *et al*., 2012). Furthermore, the existence of associated bioactive composites such as phenolic compounds (33.7 mg tannic acid equivalents/g extract), flavonoids (4.52 mg quercetin/gram), and vitamin C with antioxidant properties in fresh lemon albedo (the spongy and cellulosic layer of the lemon peel) provides healthier benefits than other dietary fiber sources (Akbarian *et al*., 2013; Mari´n *et al*., 2002).

According to Abbasi *et al*. (2015), dietary citrus pulp boosted broiler feed intake and growth performance across the entire production cycle while lowering liver and abdominal fat. Dried lemon pulp, according to Nobakht (2013), increased chicken growth performance across the full production period. Dietary citrus has also been found to lift the nutritional value of cattle meat (Ibrahim *et al*., 2011). In accordance, it is reasonable to assume that including dried citrus peel in the broiler diet will boost the broiler's growth and meat yield. Therefore, the present study was designed to explore the effects of incorporation of dried orange peel (DOP) and dried lemon peel (DLP) in broiler diet on the growth performance, carcass parameters and profitability of broiler rearing.

Materials and Methods

The experiment was accomplished under the Department of Agribusiness of Atish Dipankar University of Science and Technology, Dhaka, Bangladesh.

Preparation of experimental additives

After extracting juice from fresh oranges and lemons, the peels were gathered. Following that, both citrus peels were dried in the sun using the procedure described by Farahmandfar *et al*. (2019). The samples were dried until they had a moisture content of 10%. The peels were ground in a household grinder after drying. The additives will be added at the expense of a proportionate amount of the basal diet.

Experimental design and dietary treatments

A total of 200 one-day-old Cobb 500 broiler chicks were purchased from a commercial hatchery, weighed, and randomly allocated into five treatment groups with four replicate pens of ten birds in a completely randomized design. The dietary treatments were as follows: (1) basal diet without any supplementation (basal); (2) basal diet plus 0.5% DOP; (3) basal diet plus 0.5% DLP; (4) basal diet plus 1.0% DOP; (5) basal diet plus 1.0% DLP. All of the diets were applied in mashed form during the starter (0–21 days) and grower (22–35 days) periods.

The basal diet was a commercial maize soybean meal-based mashed diet formulated to suit the nutritional needs of broiler chickens.

Bird managements

Broilers were kept in an open-sided broiler house with a stoking density of 1 sq. ft./bird that had been thoroughly cleaned, washed, and disinfected prior to the arrival of the chicks. The chicks were given a glucose solution when they arrived to help them cope with the stress of transport. Round feeder and round drinker were installed in the house to allow for unlimited feed and water consumption. Feeding and drinking areas were allocated based on the number and age of the birds. Electric light was provided over 24 hours and the temperature of the house was maintained from 34ºC to 26ºC throughout the experimental period. Sawdust was used as litter at a depth of 5 cm. Strict recommended vaccination program and if require medication was followed. Strict hygienic measures and sanitation program of the experimental house was maintained during experimental period.

Measurement of parameters

Growth performance

The birds were reared up to 35 days of age. Body weight (BW) was recorded per pen on a weekly basis from the initial day to the final day of the experiment. In addition, feed intake for each pen was calculated by measuring feed residue on the same days as the birds were weighed. The average daily feed intake (ADFI), average daily gain (ADG), and FCR (feed to gain ratio) per pen were then calculated by period and for the entire experimental period. Chicks were inspected daily and dead birds were removed following recoding of mortality (pen, date, and body weight). The gain, feed intake, and feed conversion were corrected for dead birds.

Slaughter and sampling procedure

Five chickens per treatment were indiscriminately selected and slaughtered at the end of the experiment to calculate meat yield and internal organ development. Feed was removed 8 hours before slaughtering to make broiler processing easier, but water was delivered on a regular basis. To calculate the dressing %, the live weight and dressed weight were recorded. By removing the skin, bones, and connective tissue, the breast, thigh drumstick, and wing meat were separated from the carcass, and the percentages of breast, thigh drumstick, and wing meat were estimated using the formula:

$$\text{Breast/ thigh/ drumstick/wing meat percentage} = \frac{\text{breast/thigh/drumstick/wing absolute weight} \times 100}{\text{live body weight}}$$

The crop, proventriculus, heart, liver, spleen, gizzards, pancreas, kidney, small intestine, big intestine, cecum, abdominal fat, and bursa of Fabricius were all taken out and weighed. Organ relative weights (%) were determined by calculating the weights of individual organs with respect to live body weight.

Calculation of profitability

Cost benefit analysis was performed at the end of trial to justify the use of additives. From the beginning through the end of the experiment, all variables and fixed-cost units were meticulously included as routine inventory systems. The cost benefit was calculated as BDT/bird (basis) and BDT/kg live weight (basis). The productive efficiency index (PEI) was calculated by taking into account body weight, livability, bird age, and feed conversion ratio and was calculated according to the following equation:

PEI (%) = [weight (kg) x livability (%) x 100]/ [Age (days) x feed conversion ratio]

Statistical analysis

All data were analyzed in a completely randomized design by ANOVA using the SAS (2003) General Linear Model (GLM) method. For growth performance and profitability, individual pen was used as the experimental unit, whereas individual bird served as the experimental unit for meat yield and organ weight development. Differences with p-values <0.05 or better were considered to be significant.

Results and Discussion

Growth performance

As an indicator of growth performance upon DOP and DLP supplementation, we determined BW, ADG, ADFI and FCR of broilers (Table 1). During starter period the final BW and ADG of broilers supplemented with 0.5% and 1.0% DLP was significantly higher ($P < 0.05$) than that of control and 0.5% DOP. However, during finisher and overall experimental period the BW and ADG were significantly higher in the 0.5% DLP, 1.0% DOP and 1.0% DLP supplemented groups compared to control group ($P < 0.05$). The ADFI of broilers did not differ significantly among the dietary treatments throughout the experimental period. Improved FCR was found in the 0.5% DLP, 1.0% DOP and 1.0% DLP supplemented groups compared to control and 0.5% DOP supplemented group ($P<0.05$) during the overall experimental period.

Table 1. Effects of dried citrus peel by-products on the production performance of broilers (0 to 35 days)[1].

Performance parameter	Dietary treatments[2]					SEM[3]	P-value
	Control	DOP 0.5%	DLP 0.5%	DOP 1.0%	DLP 1.0%		
Starter period (0 to 21 days)							
Initial body weight	44.92	45.45	45.44	45.14	45.22	0.22	NS
Final body weight	918.69^{b}	946.50^{b}	1013.63^{a}	978.56^{ab}	1020.56^{a}	43.48	0.05
Weight gain (WG)	873.77^{b}	901.05^{b}	968.19^{a}	933.42^{ab}	975.34^{a}	43.37	0.05
Average daily gain (ADG)	41.61^{b}	42.91^{b}	46.10^{a}	44.45^{ab}	46.44^{a}	2.07	0.05
Average daily feed intake (ADFI)	62.31	62.29	62.26	63.63	62.63	0.58	NS
Feed conversion ratio (FCR)	1.50^{b}	1.45^{ab}	1.35^{a}	1.43^{ab}	1.35^{a}	0.07	0.05
Finisher period (22 to 35 days)							
Initial body weight	918.69^{b}	946.50^{b}	1013.63^{a}	978.56^{ab}	1020.56^{a}	43.48	0.05
Final body weight	1794.38^{b}	1851.25^{ab}	1916.25^{a}	1940.25^{a}	1965.23^{a}	69.75	0.05
Weight gain (WG)	875.69^{b}	904.75^{ab}	902.62^{ab}	961.69^{a}	944.67^{a}	34.72	0.05
Average daily gain (ADG)	58.38^{b}	60.32^{ab}	60.17^{ab}	64.11^{a}	62.98^{a}	2.31	0.05
Average daily feed intake (ADFI)	110.36	108.72	109.37	110.71	107.34	1.35	NS
Feed conversion ratio (FCR)	1.89^{b}	1.80^{ab}	1.82^{ab}	1.73^{a}	1.70^{a}	0.07	0.05
Overall period (0 to 35 days)							
Initial body weight	44.92	45.45	45.44	45.14	45.22	0.47	NS
Final body weight	1794.38^{b}	1851.25^{ab}	1916.25^{ab}	1940.25^{a}	1965.23^{a}	69.75	0.05
Weight gain (WG)	1749.46^{b}	1805.80^{ab}	1870.81^{a}	1895.11^{a}	1920.01^{a}	69.67	0.05
Average daily gain (ADG)	49.98^{b}	51.59^{ab}	53.45^{a}	54.15^{a}	54.86^{a}	1.99	0.05
Average daily feed intake (ADFI)	84.68	83.97	84.23	85.63	83.58	0.79	NS
Feed conversion ratio (FCR)	1.69^{b}	1.63^{ab}	1.58^{a}	1.58^{a}	1.52^{a}	0.06	0.05

Same letters within a raw indicate non-significant and different letters indicate statistically significant at 5% level ($p<0.05$).
[1]Values represent the means of four pens with ten birds per pen.
[2]Control, DOP 0.5% = Basal diet+0.5% dried orange peel, DLP 0.5% = Basal diet+0.5% dried lemon peel, DOP 1.0% = Basal diet+1.0% dried orange peel, DLP 1.0% = Basal diet+1.0% dried lemon peel
[3]SEM = Pooled standard error.

The results of our study are supported by the findings of Ebrahimi *et al*. (2014) who supplemented broiler with 1000 ppm or 1250 ppm *Citrus sinensis* peel extract for 42 days and found significantly higher final body weight. Ahmed *et al*. (2014) also reported significantly higher BW and ADG in broilers supplemented with *Citrus junos* probiotic. Sahu *et al.* (2019) reported significantly increased ($P<0.05$) body weight and gain in weight in broilers when they are supplemented with lemon or orange peel essential oil either alone or in combination (200 mg/kg). Siyal *et al*. (2016) reported that broiler chicken supplemented with 1.5 and 3.0 % orange peel had significantly higher weight gain than control. Contrary to our results, Akbarian *et al.* (2013) reported no significant effects of dietary orange peel extract (OPE) and lemon peel extracts (LPE) on the weight gain, feed intake or feed conversion ratio of broiler when supplemented OPE at 0 and 200mg/kg feed and LPE at 0, 200, and 400mg/kg feed. Basir and Toghyani (2017) reported decreased body weight and weight gain in broiler supplemented with dried lemon pulp at 2.5, 5, and 7.5%; in starter 5, 7.5, and 10% at growing and 7.5, 10, and 12%, at finisher phases, respectively.

Carcass characteristics and meat yield of broilers

The effects of DOP and DLP supplementation on broiler carcass characteristics and meat yield are indicated in Table 2. Broiler live weight and dressed weight did not differ substantially between supplemented groups ($p > 0.05$). However, when compared to the control group, the dressing percentage was significantly higher in all supplemented groups ($P<0.05$). When compared to the control and 0.5% DOP groups, the proportion of breast meat in the 0.5% DLP, 1.0% DOP, and 1.0 % DLP supplemented groups was higher ($P < 0.05$). Broiler thigh, drumstick, and wing meat proportions did not differ significantly between treatment groups. Siyal *et al*. (2016) reported that broiler chicken supplemented with 1.5 and 3.0% orange peel had significantly higher carcass weight and dressing percentage than control. Citrus peel extract was discovered to raise the circulation total protein content in chicken blood, possibly due to improved nutritional absorption (Akbarian *et al*.,

2013). Citrus peel extract can limit the growth of pathogenic bacteria, encourage the establishment of probiotic microflora (Pourhossein *et al*., 2012), and increase nutrient absorption in the intestinal epithelium, in addition to providing several vitamins with anti-oxidant effects. All of these factors could have influenced nutrition use and, as a result, enhanced weight gain and carcass yield.

Table 2. Effects of dried citrus peel by-products on the meat yield characteristics of broiler weight and organ weight of broiler[1].

Parameter	Dietary treatments[2]					SEM[3]	P-Value
	Control	DOP 0.5%	DLP 0.5%	DOP 1.0%	DLP 1.0%		
Live weight (g)	1840.88	1850.25	1856.25	1884.25	1865.23	16.49	NS
Dressed weight (g)	1150.89	1194.23	1195.35	1206.45	1218.45	25.54	NS
Dressing %	62.52^{b}	64.54^{a}	64.40^{a}	64.03^{a}	65.32^{a}	1.03	0.05
Absolute Breast weight (g)	359.00^{b}	383.25^{b}	408.75^{a}	412.25^{a}	410.23^{a}	23.20	0.05
Absolute Thigh weight (g)	244.00	268.75	286.24	293.50	289.22	27.38	NS
Absolute Drumstick weight (g)	224.56	234.22	239.78	244.89	251.32	17.23	NS
Absolute wing weight (g)	196.99	203.44	211.65	208.67	221.33	12.12	NS
Relative breast weight (%)	19.50^{b}	20.71^{b}	22.02^{a}	21.88^{a}	21.99^{a}	1.10	0.05
Relative thigh weight (%)	13.25	14.53	15.42	15.58	15.51	0.99	NS
Relative Drumstick weight (%)	12.20	12.66	12.92	13.00	13.47	0.47	NS
Relative wing weight (%)	10.70	11.00	11.40	11.07	11.87	0.44	NS

Same letters within a raw indicate non-significant and different letters indicate statistically significant at 5% level ($p<0.05$).
[1] Values represent the means of five chickens per treatments.
[2] Control, DOP 0.5% = Basal diet+0.5% dried orange peel, DLP 0.5% = Basal diet+0.5% dried lemon peel, DOP 1.0% = Basal diet+1.0% dried orange peel, DLP 1.0% = Basal diet+1.0% dried lemon peel
[3] SEM = Pooled standard error.

Table 3. Effects of dried citrus peel by-products on internal organ weight of broiler[1].

Relative Organ weight (%)	Dietary treatments[2]					SEM[3]	P-Value
	Control	DOP 0.5%	DLP 0.5%	DOP 1.0%	DLP 1.0%		
Crop	0.33	0.27	0.31	0.29	0.31	0.02	NS
Proventriculus	0.34	0.38	0.36	0.41	0.39	0.03	NS
Heart	0.44	0.43	0.39	0.39	0.44	0.03	NS
Liver	1.92	1.72	1.69	2.12	1.98	0.18	NS
Spleen	0.08^{b}	0.08^{b}	0.11^{a}	0.09^{b}	0.12^{a}	0.02	0.05
Gizzard	1.32	1.54	1.42	1.27	1.45	0.11	NS
Pancreas	0.17	0.29	0.14	0.18	0.19	0.06	NS
Kidney	0.55	0.63	0.62	0.52	0.59	0.05	NS
Small intestine	2.15	2.33	2.53	2.68	2.44	0.20	NS
Large intestine	0.17	0.16	0.15	0.16	0.15	0.01	NS
Cecum	0.51	0.52	0.52	0.49	0.45	0.03	NS
Abdominal fat	1.83^{a}	1.79^{a}	1.49^{b}	1.81^{a}	1.44^{b}	0.19	0.05
Bursa	0.33	0.27	0.31	0.29	0.31	0.02	NS

Same letters within a raw indicate non-significant and different letters indicate statistically significant at 5% level ($p<0.05$).
[1] Values represent the means of five chickens per treatments.
[2] Control, DOP 0.5% = Basal diet+0.5% dried orange peel, DLP 0.5% = Basal diet+0.5% dried lemon peel, DOP 1.0% = Basal diet+1.0% dried orange peel, DLP 1.0% = Basal diet+1.0% dried lemon peel
[3] SEM = Pooled standard error.

Internal organ weight of broilers

The relative weights of the crop, proventriculus, heart, liver, gizzard, pancreas, kidney, small intestine, large intestine, cecum, belly fat, and bursa were not affected by the food regimens ($P > 0.05$). However, in the 0.5% and 1.0% DLP supplemented groups, the relative weight of the spleen was significantly higher, while the relative weight of abdominal fat was significantly lower. Basir and Toghyani (2017) found that food supplementation of 5, 7.5, and 10% dried lemon pulp increased the spleen weight of broilers, corroborating our findings. The spleen of an avian is a secondary immune organ and spleen's size is regarded to be a good indicator of a bird's ability to mount an immunological response (John, 1994; Smith and Hunt, 2004). The availability of significant levels of citric acid in the lemon peel, which may increase fat metabolism, could explain the lower belly fat content in the 0.5% and 1.0% DLP supplemented groups (Fik *et al*., 2021). Ebrahimi *et al*. (2014) reported reduced abdominal fat in broilers treated with 1000 ppm or 1250 ppm of *Citrus sinensis* peel extract for 42 days. Basir and Toghyani (2017), on the other hand, reported no significant impacts of dried lemon pulp on abdominal fat.

Profitability analysis

The comparative economic analysis of experimental treatments is shown in Table 4. When compared to control, the feed cost per broiler in the 1.0% DOP supplemented group was higher, followed by DLP 1.0%, DLP 0.5%, and DOP 0.5%. The total cost per broiler followed a similar pattern. The control group had the highest net profit per broiler and profit per kg live weight (BDT 35.01 and BDT 19.02, respectively), followed by the 1.0% DLP supplemented group (BDT 34.14, BDT 18.30, respectively). When compared to control, the 1.0% DLP supplemented group had the greatest Production Efficiency Index (PEI), followed by 1.0 percent DOP, 0.5 percent DLP, and 0.5

percent DOP supplemented groups. In contrast to our findings, Sahu *et al*. (2019) found that adding lemon and orange peel to the food increases the net return per bird. The inclusion of the purchase price of oranges and lemons may have resulted in decreases in net profit per bird and profit per kg of live weight. The net profit may improve if the peels can be collected from any fruit processing industry. However, in our trial, the supplemented groups' production efficiency index was higher than the control groups', indicating that dietary supplementation with orange and lemon peel was economically viable.

Table 4. Economics of broiler production fed different dried citrus peel[1].

Parameter	Dietary treatments[2]				
	Control	DOP 0.5%	DLP 0.5%	DOP 1.0%	DLP 1.0%
Cost/chick (Taka)	25.00	25.00	25.00	25.00	25.00
Average feed consumed (kg)/chicks	2.96	2.94	2.95	3.00	2.93
Feed price (Tk/kg)	47.00	48.50	48.50	49.25	49.00
Feed cost/broiler (Tk)	139.30	142.54	142.98	147.60	143.34
Cost of treatment (Tk)	10.00	10.00	10.00	10.00	10.00
Fixed cost (Tk)	30.00	30.00	30.00	30.00	30.00
Total cost/bird (Tk)	204.30	207.54	207.98	212.60	208.34
Average live weight (kg)	1.84	1.85	1.86	1.88	1.87
Sale price/kg (Tk)	130.00	130.00	130.00	130.00	130.00
Sale price/broiler	239.31	240.53	241.31	244.95	242.48
Net profit/broiler	35.01	33.00	33.33	32.36	34.14
Profit/kg live weight (Tk)	19.02	17.83	17.96	17.17	18.30
Production Efficiency Index (PEI)	294.01	307.86	317.25	321.56	331.30

[1] Values represent the means of four pens with ten birds per pen.
[2] Control, DOP 0.5% = Basal diet+0.5% dried orange peel, DLP 0.5% = Basal diet+0.5% dried lemon peel, DOP 1.0% = Basal diet+1.0% dried orange peel, DLP 1.0% = Basal diet+1.0% dried lemon peel.

Conclusion

Finally, adding dried orange peel (DOP) and dried lemon peel (DLP) to broiler diets enhanced final body weight, weight gain, FCR, dressing percentage, and breast meat output. However, the dietary treatments had no effect on broiler feed intake. The DLP supplemented group had a higher spleen weight and a lower abdominal fat weight. Although the supplemented group's net profit per bird and profit per kg live weight were lower, the production efficiency index was higher in comparison to control group. As a result, it can be stated that supplementing broiler chickens with dried lemon and orange peel had a beneficial influence on production performance and meat yield, and hence can be recommended as feed additives.

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Conflict of interests

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

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