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Effect of Dietary Supplementation of Linseed Oil and Natural Antioxidants on Production Performance, Fatty Acid Profile and Meat Lipid Peroxidation in Broilers

Anjumoni Mech, Umaya Suganthi, Somu Bala Nageswara Rao, Veerasamy Sejian, Manik Soren, Corbon David, Vaibhav Awachat, Veeranna Kadakol

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ABSTRACT

Background: Healthy omega-3 fatty acid (n-3FA) enriched poultry meat can be achieved through dietary supplementation of n-3 FA rich feed ingredients like fish meal, linseed, linseed oil, marine algae, etc to broiler birds. A study was conducted to investigate the effect of supplementing linseed oil (LO) in combination with natural antioxidants like curry leaf powder, ginger powder and turmeric powder to explore the additional benefits of these natural antioxidants in reducing meat lipid peroxidation.

Methods: Day-old male broiler chicks (n=150) were randomly allotted to five dietary treatments, namely, 2% vegetable oil (C), 2% linseed oil (LO), 2% LO + 0.5% curry powder (LOC), 2% LO + 0.5% ginger powder (LOG) and 2% LO + 0.5% turmeric powder (LOT) for 42 days.

Result: Results showed highest average daily gain (ADG) and best feed conversion efficiency (FCE) in LOG group compared to all other groups. The effect of different treatment was not evident on other production parameters. The omega-6: omega-3fatty acid ratio (n-6 FA: n-3 FA) was enhanced in all LO supplemented broilers. Supplementation of dietary natural antioxidants along with LO did not have any significant impact on meat lipid peroxidation which was analyzed by quantifying malondialdehyde production rate. It may be inferred that feeding LO to broiler chicks' produces n-3 FA enriched chicken meat but the effect of natural antioxidants like curry leaf, ginger and turmeric powder on meat lipid peroxidation could not be established through the present study.

Key words: Antioxidant, Broiler, Fatty acids, Linseed oil, Omega-3 FA.

INTRODUCTION

Chicken meat is preferred over other meat for its higher protein and low cholesterol content. For human health, meat should contain an adequate amount of polyunsaturated fatty acid (PUFA) preferably balanced omega-6 and omega-3 fatty acid (Bhalerao *et al*., 2014). Generally omega-6 fatty acid (n-6FA) content is more as compared to omega-3 fatty acid (n-3 FA) in chicken and other meat. Modification of carcass fatty acid content of chicken through dietary supplementation of linseed oil (LO) has been successful (Betti *et al*., 2009). The linseed oil is one of the richest dietary sources of α-Linolenic acid (ALA; n-3 FA) vital for various physiological functions (Nyquist *et al*., 2013). Chicks can convert ALA through desaturation and elongation reactions to Eicosopentaenoic acid (EPA) and Docosahexaenoic acid (DHA) that are functionally most important PUFAs in human metabolism. Linoleic acid (18:2 n-6) and a-linolenic acid (ALA 18:3 n-3) are considered to be the only essential fatty acids for poultry. It is possible to obtain chicken meat enriched with ALA, EPA and DHA by feeding ALA enriched feed to chicks (Bhalerao *et al*., 2014). Nevertheless, a widely encountered problem of such dietary supplementation has been oxidation of unsaturated fatty acid in muscles resulting in rancid flavor development and deterioration in meat quality (O'Keefe *et al*., 1995). Dietary supplementation of synthetic antioxidants has been found to prevent such lipid peroxidation. Study on effect of addition of selenium (0.3 mg sodium selenite/kg diet) and vitamin E (200 mg α-tocopheryl acetate/ kg diet) in broiler diet enriched with n-3 fatty acids (15% flax seed diet) on meat quality showed that vitamin E and selenium can be added to broiler diet to protect against meat oxidation during storage (Taulescu *et al*., 2011). But there are limitations on the usage of synthetic antioxidants due to consumer's concern over their adverse effect on health. Generally, consumers prefer highly nutritious food that is protected by natural applications and free of synthetic residues and chemical preservatives. This limits the industry in their use of currently allowed synthetic antioxidants in foods, leaving manufacturers with few options (Dominguez *et al*., 2019). The natural plant polyphenols in the culinary

ICAR-National Institute of Animal Nutrition and Physiology, Adugodi, Bangalore-560 030, Karnataka, India.

Corresponding Author: Anjumoni Mech, ICAR-National Institute of Animal Nutrition and Physiology, Adugodi, Bangalore-560 030, Karnataka, India. Email: anjumoni_0071@yahoo.co.in

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herbs improve body weight, weight gain and feed conversion efficiency (FCE) and hence can be used as efficient growth promoters in chicken (El-Maaty *et al*., 2014). Consequently, attention has been paid to the incorporation of natural antioxidants into the diet of meat animals and birds. Several spices used in traditional Indian cuisine have been shown to possess antioxidative properties; curry leaf (*Murraya koenijii*), ginger (*Zingiber Officinale* Roscoe) and turmeric powder (*Curcuma longa*) to name a few (Moorthy *et al*., 2009; Zhang *et al*., 2009). The antioxidative properties of the bioactive compounds present in all these spices have been studied both in vitro and *in vivo* (Rao *et al*., 2007; Puengphian *et al*., 2008). But there is no study on effectiveness of curry leaf, ginger, or turmeric powder supplementation along with omega-3 enriched diet in production performance and meat lipid peroxidation in broilers. Thus, the goal of the current research was to enrich broiler chicken meat with n-3 FA by feeding LO and simultaneously test the effectiveness of dietary supplementation of curry leaf, ginger and turmeric powder, on overall performance, fatty acid profile and meat antioxidative status in broilers.

MATERIALS AND METHODS

Day-old male broiler chicks (n =150) from single hatch were weighed and randomly allotted to five groups with five replicates per group and six birds per replicate (30/group). The birds were housed in three-tier battery cages with ad lib access to feed and water. The birds were weighed weekly once up to day 42. The feed offered and leftovers were measured every day to evaluate the performance of broilers. The performance of broilers was evaluated in terms of average daily gain (ADG), average daily feed intake (ADFI) and feed conversion efficiency (FCE).

The experiment was conducted during the year 2014 at the experimental shed of ICAR-National Institute of Animal Nutrition and Physiology. The experimental procedure was approved by the Animal Care Guidelines of Institute Animal Ethics Committee of ICAR-National Institute of Animal Nutrition and Physiology which is under the Committee for Control and Supervision on Experiments on Animals (CPCSEA), India.

The basal maize-soybean based diet (Panda *et al*., 2002) was supplemented with 2% vegetable oil (Control), 2% LO (LO), 2% LO + 0.5% curry leaf powder (LOC), 2% LO + 0.5% ginger powder (LOG) and 2% LO + 0.5% turmeric powder (LOT). The calculated and analyzed nutrient composition is given in table1 and table 2. In the beginning; the basal ration was prepared without adding oil. Each week a portion of feed from the ration was added with vegetable oil and linseed oil and then mixed thoroughly before offering to the birds. Adding 2% LO to starter and grower diet resulted in an enhancement in dietary ALA (n-3 FA), compared to control (Table 3). Conversely linoleic acid (n-6 FA) content was almost two-fold more in the control diet.

On day 42 of the experiment, all birds were weighed and two birds of average body weight from each replicate were slaughtered. After mechanical stunning, the birds were bled for 2-3 minutes and blood was collected in a centrifuge tube containing heparin for harvesting plasma. The carcass characteristics were recorded and breast muscle samples were stored at-80°C for analyzing the fatty acid composition.

The pectoralis major muscle (~100 g) was longitudinally cut from the carcass at 24 h post mortem, weighed and suspended in a plastic zip-lock pouch at 4°C. After 48 hrs, exudates were discarded, the samples were weighed and drip loss was calculated.

For meat lipid peroxidation determination, breast muscle samples from each bird were wrapped in aluminum foil into four replicates. The first replicate was processed on day 0 as per the standard procedure (Pikul *et al*., 1989). Subsequently on day 4, day 7 and day 14three replicates were taken out from 4°C storage, processed and processed filtrates were stored at -20°C and subsequently, malondialdehyde (MDA) was estimated as per the standard protocol (Pikul *et al*., 1989). The total antioxidant capacity (TAC) was measured in plasma samples by using the TAC colorimetric kit from BioVision (Milpitas, USA).

A simplified protocol (O'Fallon *et al*., 2007) was followed to obtain fatty acid methyl esters (FAME) directly from wet tissue samples. Then FAME was analyzed by gas chromatography (Agilent model 7890A series with FID detector) equipped with HP-88 capillary column (100 m × 0.25 mm × 0.20 µm). The calibration and peak determination was done by FAME mix standards, (Sigma Aldrich, St. Louis, USA).

Data were analyzed in PASW 18 software package for Windows (SPSS Inc. Version18:0. 2009). The effect of

Table 1: Composition and nutritive value of basal diets fed to broiler birds during 1to 21 days and 22 to 42 days of age.

Ingredient (%)	Age group	
	1 to 21 day	22 to 42 days
Maize	59.00	62.05
Soyabean meal	34.80	31.90
Vegetable oil/Linseed	2.00	2.00
Curry/ginger/turmeric powder	0.5	0.5
Calcium carbonate	1.00	1.00
Dicalcium phosphate	1.80	1.50
Mineral premix	0.25	0.50
Salt	0.35	0.35
Lysine	0.20	0.10
Methionine	0.10	0.10
Calculated nutritive value		
ME, kcal/kg	2980.98	3004.18
Protein, %	21.42	20.28
Crude Fat, %	5.06	5.12
Crude Fibre, %	3.61	3.50
Calcium, %	1.02	1.04
Available Phosphorus, %	0.39	0.37
Sodium, %	0.14	0.14
Lysine, %	1.00	0.93
Mehionine, %	0.35	0.34
Cysteine, %	0.25	0.23

Table 2: Analyzed nutritional composition (%) of starter and finisher ration fed to experimental broiler chickens.

Groups	DM	TA	OM	EE	CF	CP
Starter ration composition						
C	92.90	7.07	92.94	4.56	3.40	23.20
LO	92.73	6.75	93.25	3.96	3.90	21.68
LOC	92.58	6.90	93.11	3.99	3.12	23.50
LOG	92.94	6.63	93.38	4.00	3.36	20.35
LOT	92.99	6.88	93.13	3.70	3.28	20.60
SEM	0.04	0.05	0.05	0.10	0.14	0.36
Finisher ration composition						
C	93.00	8.28	93.08	4.19	3.58	21.60
LO	92.81	6.45	93.56	4.02	4.10	20.23
LOC	92.43	7.87	92.14	4.35	4.05	20.10
LOG	92.66	7.22	92.78	4.09	3.89	21.22
LOT	93.07	7.43	92.57	4.00	3.27	21.82
SEM	0.10	0.24	0.13	0.07	0.07	0.23

DM, dry matter; TA, total ash; OM, organic matter; EE, ether extract; CF, crude fibre; CP, crude protein.

Table 3: Fatty acid composition (mg/g feed) in broiler diets under different experimental groups during 1 to 21 days and 22-42 days of age.

Fatty acid	1 to 21 day					22 to 42 day					P -value
	C	LO	LOC	LOG	LOT	C	LO	LOC	LOG	LOT	
14:0	0.06	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.05	n.s.
16:0	7.07	6.31	6.17	5.23	6.78	6.32	7.18	6.24	6.08	6.68	n.s.
16:1	0.11	0.07	0.07	0.07	0.08	0.08	0.09	0.08	0.07	0.08	n.s.
18:0	18.24	15.02	14.38	12.90	16.33	16.75	18.34	16.06	15.15	16.85	n.s.
18:n9	0.49	0.43	0.43	0.37	0.47	0.44	0.51	0.45	0.42	0.47	n.s.
18:2n6	37.12^{a}	20.53^{b}	20.39^{b}	16.93^{b}	22.17^{b}	32.07^{a}	24.08^{b}	20.70^{b}	20.27^{b}	22.56^{b}	0.01
18:3n3	2.89^{a}	13.56^{b}	12.07^{b}	13.58^{b}	13.04	2.90^{a}	13.06^{b}	14.1^{b}	12.69^{b}	14.36^{b}	0.01
20:1n9	0.63	0.58	0.55	0.51	0.64	0.60	0.69	0.58	0.55	0.62	n.s.

n.s., not significant.

Within rows, the values with different superscripts are statistically different ($P < 0.05$).

different feeding treatment on production performance was analyzed by one way ANOVA. The data for MDA were subjected to repeated measures with a mixed model considering time and treatment interaction. The effect of test diets on fatty acid composition was analyzed by multivariate ANOVA. A significant difference among all the measured parameters was analyzed by Tukeys' test.

RESULTS AND DISCUSSION

Production performance

The effects of feeding LO, curry, ginger and turmeric powder, on broiler performance, is shown in Table 4. The performance parameters like average daily feed intake (ADFI, g/d/bird), average daily gain (ADG, g/d/bird) and feed conversion efficiency (FCE) were affected ($P<0.01$) by dietary supplementation. The ADFI was found lowest in the LOG group without any adverse effect on growth performance. According to previous reports chick may tolerate up to 1.5% ginger powder in the diet (Zomrawi *et al*., 2013) and significantly reduced feed intake was observed in 1.5% and 2% dried red ginger meal fed broilers (Herawati, 2010; Zomrawi *et al.,* 2013). Supplementation of turmeric was found to have no significant impact on body weight gain and daily feed intake and was consonant with earlier studies in poultry (Nouzarian *et al.,* 2011). In our study the ADG and total weight gain were significantly ($P < 0.01$) higher in antioxidant and LO supplemented groups compared to only LO fed group. This indicates beneficial effect of natural antioxidant supplementation in combination with LO rather than sole supplementation of LO. Similarly no influence of LO supplementation was observed on performance parameters like weight gain, feed intake and FCE in broilers earlier (Olomu and Baracus, 1991). Conversely some

Table 4: Average daily feed intake (ADFI), average daily gain (ADG) in body wt. and feed conversion efficiency (FCE) in broilers under different treatment groups.

Treatment groups	ADFI (g/d, per bird)	ADG (g/d, per bird)	FCE (g/g)	Total wt gain (kg/bird)
C	110.90^{ab}	60.07^{a}	1.85^{a}	2.52^{a}
LO	112.66^{ab}	53.61^{b}	2.10^{b}	2.25^{b}
LOC	114.67^{ab}	59.92^{a}	1.92^{ab}	2.52^{a}
LOG	105.07^{a}	60.39^{a}	1.74^{a}	2.54^{a}
LOT	117.83^{b}	59.59^{a}	1.98^{b}	2.50^{a}
SEM[a]	1.20	0.68	0.03	0.03
P- value	0.004	0.001	0.001	0.001

[a]Pooled SEM (standard error mean) value.

Within rows, the values with different superscripts are statistically different ($P< 0.05$).

studies stated that, dietary fatty acid profile influences better body weight gain in broilers fed with omega 3 rich oil sources like sunflower oil, canola oil and soya bean oil compared to saturated fat rich palm oil as presence of polyunsaturated fatty acids has better intestinal absorption due to hydrolysis of monoglyceride and micelle formation compared to saturated fatty acids (Poorghasemi *et al.,* 2018). Similarly feeding of omega 3 rich rapeseed oil at 0.75 to 1.5% level was reported to improve the production performance in broilers (Sudharsan *et al.,* 2020). In our study, the FCE in the birds of LOG diet was found best with highest ADG and total weight gain and lowest ADFI. It was reported that supplementation of 1% ginger in the diet stimulate lactic acid bacteria and decreases pathogenic bacteria such as mesophilic aerobic, coliform and *Escherichia coli* and thus improves absorption of nutrients along with increase villi length and width thereby enhancing digestibility leading to better weight gain of the birds (Karangiya *et al*., 2016). Supplementation of 0.5% ginger with highest body weight gain and best FCE followed by 0.5% turmeric feeding in broiler chicks was reported earlier (Awadein *et al.,* 2012; Kafi *et al.,* 2017). Significantly (P<0.05) higher total body weight gain was obtained in broiler birds fed 1% ginger root powder in response to simultaneous increase in feed intake and it was attributed to antioxidant activity of ginger enhancing the digestibility of feed along with pungent test or aroma and flavor of ginger (Mohammed *et al*. 2014). Consequently all these studies proved positive impact of ginger on nutrient digestibility and growth performance in broilers due to its antioxidant properties. Several studies reported improvement of growth performance in broilers fed with a diet supplemented with curry leaf powder alone or in combination with ginger powder due to improved nutrient digestibility and antioxidant properties (Moorthy *et al*., 2009; Rao *et al*., 2011; Jain *et al*., 2012; Jayathilaka *et al*., 2018).

Nevertheless, the dressing percentage and hot carcass wt did not differ significantly (Table 5). Earlier study suggested that supplementation of n-3 fatty acid sources like fish oil and linseed oil at 3.9 percent did not have any adverse effects on the performance parameters and carcass parameters such as dressing yield, breast yield, liver and giblet (Bharath *et al*., 2017). Similar investigations in broiler birds fed with different levels and combinations of pepper, ginger and curry leaf powder were found to have no significant effect on carcass characteristics, pre-slaughter weight, dressed weight and eviscerated wt (Moorthy *et al*., 2009). The ability of fresh meat to retain moisture is considered as one of the most important characteristics of raw meat. Drip loss reduces the weight of saleable meat products as well as eating quality. The drip loss of 1.61 to 2.64% in the present study signifies that the protein fluid loss from the fresh meat was insignificant and was unaffected by the oil supplementations as reported elsewhere (Hang *et al.,* 2018). Previously experiment conducted in Ross male broiler birds reared up to d 42 to observe the effect of different period of pre-slaughter fasting period (4-16 h) and water spray could reveal comparatively higher drip loss in chicken meat ranging between 3.6 to 4.95% (Komiyama *et al.,* 2008) as compared to present findings.

Enrichment of n-3 FA in chicken meat

Feeding 2% LO for 42 days has enhanced overall n-3 FA content by more than two folds (P<0.01) in broiler birds (Table 6). This enhancement of total n-3 FA concentration (4.27 to 6.15 mg/g of meat) in breast muscle in response to LO feeding was due to an increase in ALA (18:3n3). The breast muscle content of EPA (20:5n3), DPA (22:5n3) and DHA (22:6n3) and total PUFA was higher in LO-fed groups and highest total PUFA was assessed in birds fed LOC diet. The n-3 FA enrichment was primarily due to a tripling of ALA levels in the breast meat and the ability of birds to desaturate and elongate ALA to EPA. Simultaneously it has resulted in enhanced n-6 FA to n3 FA ratio in all 2% LO supplemented groups. Nevertheless, the best n-6 to n-3 FA ratio was calculated for birds fed diet LOC followed by LOG and LOT. Earlier studies with dietary supplementation of 2% LO along with antioxidant in broiler was shown to enhance in long-chain omega-3 PUFA especially EPA and DHA in meat resulting in decrease (P≤0.001) ratio of n-6 to n-3 PUFA compared to broiler diet without antioxidants (Samee *et al*., 2019). Enrichment of chicken meat with 3 mg of n-3 FA per g meat could be acquired in 11.3 and 26.2 days with 17% and 10% level of linseed in the diet earlier (Betti *et al*., 2009). A higher n-3 FA content in chicken breast muscle was acquired in the present study by supplementing 2% LO for 42 days. According to another report broiler chicken fed with LO from 25 to 55 days of fattening period had shown effect on lipid metabolism and meat fatty acid content resulting in

Table 5: Carcass quality of broilers under different treatment groups.

Parameters	C	LO	LOC	LOG	LOT	SEM[a]	P -value
Dressed wt., kg	2.07	1.92	2.09	2.09	2.03	0.04	n.s.
Liver wt, g	59.83	53.00	62.50	50.83	56.83	1.70	n.s.
Intestine wt, g	140.33	112.83	145.00	144.00	126.33	4.77	n.s.
Gizzard wt, g	58.67	46.50	53.67	50.83	49.00	1.58	n.s.
Proventriculuswt, g	10.33	10.50	16.00	13.67	10.33	2.27	n.s.
Hot carcass wt., kg	1.81	1.70	1.81	1.75	1.79	0.04	n.s.
Dressing, %	65.78	65.80	64.88	65.10	66.32	0.39	n.s.
Drip loss, %	2.64	1.61	1.88	2.45	1.46	0.26	n.s.

Within rows, the values with different superscripts are statistically different (P < 0.05).

[a]Pooled SEM value; n.s., not significant.

Table 6: Breast muscle fatty acid composition (mg/g, meat) of broilers under different treatment groups.

Fatty acid	C	LO	LOC	LOG	LOT	SEM[a]	P- value
14:0	0.36	0.34	0.50	0.43	0.35	0.05	n.s.
15:0	0.16	0.33	0.28	0.48	0.21	0.03	n.s.
16:0	1.12[a]	2.22[ab]	2.88[ab]	3.54[b]	2.22[ab]	0.28	0.05
18:0	2.22	0.94	1.51	1.02	0.52	0.16	n.s.
20:0	0.39	0.51	0.38	0.63	0.28	0.06	n.s.
23:0	0.99	0.47	0.85	0.44	0.41	0.10	n.s.
24:0	1.05	1.26	0.78	0.44	0.39	0.11	n.s.
14:1	0.25	0.49	0.31	0.18	0.17	0.04	n.s.
16:1	0.25	0.45	0.97	0.51	0.46	0.10	n.s.
18:1	5.04	4.28	3.01	5.09	2.02	0.49	n.s.
22:1	1.25[a]	1.19	1.18	1.90	1.89	0.16	n.s
18:2n6	3.34	2.55	3.32	3.74	5.34	0.31	n.s
18:3n6	1.45[ab]	1.52[ab]	2.22[b]	1.25[ab]	0.91[a]	0.12	0.04
20:4n6	3.44[ab]	4.23[ab]	4.46[b]	2.79[ab]	2.14[a]	0.24	0.03
18:3n3	1.58[a]	4.68[b]	5.70[b]	4.33[b]	3.83[b]	0.30	0.001
20:5n3	0.07[a]	0.09[ab]	0.15[b]	0.13[ab]	0.11[ab]	0.01	0.02
22:5n3	0.07[a]	0.11[ab]	0.16[b]	0.10[a]	0.13[b]	0.01	0.02
22:6n3	0.11[a]	0.16[ab]	0.14[ab]	0.16[ab]	0.19[b]	0.01	0.02
SFA[b]	6.30	6.08	7.19	6.97	4.38	0.32	n.s.
MUFA[c]	6.80	6.32	5.48	6.68	4.54	0.53	n.s.
PUFA[d]	10.04[a]	13.34[ab]	16.15[b]	12.50[ab]	12.65[ab]	0.49	0.01
n-6 FA	8.22	8.30	9.99	7.79	8.39	0.32	n.s.
n-3 FA	1.82[a]	5.05[b]	6.15[b]	4.72[b]	4.27[b]	0.31	0.001
n-6/ n-3	4.87[a]	1.87[b]	1.64[b]	1.69[b]	2.12[b]	0.27	0.001

Means with different superscripts in the same row differ significantly (P< 0.05).

[a]Pooled SEM value; n.s., not significant; [b]SFA= Saturated fatty acid; [c]MUFA= Monounsaturated fatty acid; [d]PUFA= Polyunsaturated fatty acid.

increase n-3 FA and significant decrease in n-6 FA contents (P < 0.001) that enhanced n-6: n-3 FA ratio in the thigh and adipose tissue (Starcevic *et al*., 2014). It was justified that lower values of n-6 FA in the birds fed LO could be the result of competition between n-3 and n-6 FA for Δ5 and Δ6 desaturase enzymes that are critical in the pathways for the biosynthesis of the polyunsaturated fatty acids arachidonic, EPA and DHA. In our study, the enhancement in the n-3 FA content in chicken meat was not found to be accompanied by a decline in n-6 FA content. In another study birds supplemented with 6% LO from 21 to 84 days of age contained >80 mg EPA + DHA /100 g meat and 600 mg ALA /100 g meat, respectively, reaching the "high in n-3 PUFA" threshold in dietary recommendations (Hang *et al*., 2018). The recommendation for labeling foods as a source of n-3 fatty acid is 3 mg/g, breast meat in Canada (Betti *et al*., 2009). However, in India, no level has been fixed for labeling n-3 FA enriched meat products.

Effect on meat lipid peroxidation and total blood antioxidant status

It was found that linseed oil added to chicken diet enhanced the content of long chain n-3 PUFA and simultaneously the increased susceptibility of meat lipid to oxidation (Samee *et al*., 2019). Lipid oxidation results sensory degradation in meat and meat products leading to consumer rejection. There are several primary and secondary lipid oxidation products. Malondialdehyde (MDA) is a secondary lipid oxidation product and can be used as an indicator of meat lipid oxidation rate. Inclusion of linseed was found to decrease the oxidative stability of chicken breast meat during the frozen storage period (Rahimi *et al.,* 2011). The current study showed that MDA concentration during storage (days 4, 7 and 14) increased progressively in all groups (Fig 1). However, the trend of the increase was sharp and more progressive in the LO group compared to other antioxidant treated groups and control groups. Narciso-Gayt *et al.,* (2010) found that MDA value of meat was increased when chickens fed diet containing fish oil and linseed oil, but MDA

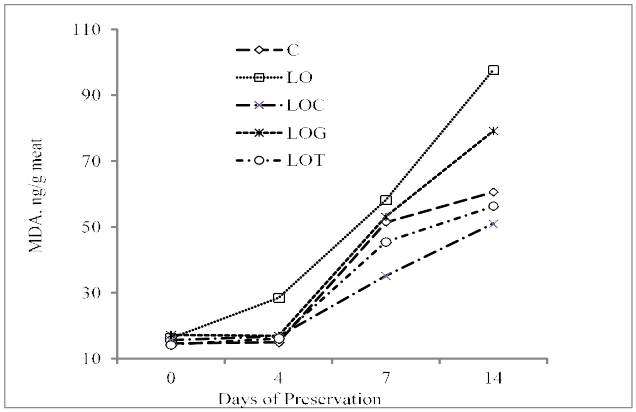

Fig 1: Lipid oxidation rate in chicken meat stored at 4°C storage temperature for 14 days indicated by mean malondialdehyde (MDA) concentration in ng/g meat.

Table 7: Plasma total antioxidant activity (TAC) in broilers under different treatment groups.

Parameter	C	LO	LOC	LOG	LOT	SEM[a]	P-value
TAC (nmol/ml)	0.83	0.77	0.86	0.82	0.85	0.01	n.s.

[a]Pooled SEM value; n.s., not significant.

value of meat was decreased when chickens fed a diet containing fish oil and linseed oil with Vit. E. Although, the graphical trend showed that curry and turmeric powder were comparatively effective in reducing lipid peroxidation rate in PUFA enriched meat, but the difference was not significant compared to control. This indicated that dietary inclusion of curry and turmeric could be regarded as effective antioxidants in the broiler birds, but a more confirmatory study is required. According to a study conducted in male broilers, dietary consumption of 5 mg turmeric rhizome powder /kg feed increased the thigh meat shelf-life storage and quality after seven days of slaughter (Daneshyar, 2012). Similarly the solvent extract of curry leaf used in ground raw pork meat stored at 4°C minimized lipid oxidation (Biswas *et al*., 2012). In our study, the effects of test diets were not reflected in plasma total antioxidant capacity (Table 7). However, compared to the control group in all the treated groups the plasma TAC was marginally enhanced. As reported earlier supplementation of ginger at the level of 5 g/kg feed in broilers enhanced total superoxide dismutase and glutathione peroxidase activity (P< 0.001) thereby improving antioxidant status and reduced (P<0.01) MDA and cholesterol concentrations in serum at day 21 and 42 of age (Zhang *et al*., 2009). Conversely, the present study could not prove the effectiveness of ginger feeding in enhancing antioxidant property and meat shelf life in broiler birds. Albeit the highest plasma, TAC was observed in the curry leaf powder feeding group and there was the marginal enhancement of plasma TAC in the ginger and turmeric feeding group, but the variation was not significant compared to the control group. The radical scavenging activity of several carbazole alkaloids from curry leaves has been ascertained previously (Tachibana *et al*., 2003).

CONCLUSION

It could be intervened from the present study that dietary supplementation of LO in broiler chicks for a duration of six weeks could produce n-3 FA enriched chicken meat. Simultaneously it did not affect the quality and characteristics of chicken meat adversely. In combination with LO, dietary curry leaf, turmeric powder, or ginger powder as a source of natural antioxidants had no impact on reducing meat lipid peroxidation during storage.

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