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Growth Performance, Carcass Traits and Meat Quality in Broilers, Fed Flaxseed Meal

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ABSTRACT : The effect of flaxseed meal on broiler performance, carcass characteristics, alpha-linolenic acid contents, and organoleptic characteristics of chicken meat was studied during a 42 day experiment. Broiler chicks were randomly allotted to 4 experimental groups and fed iso-energetic and iso-nitrogenous diets containing flaxseed meal at 0, 5, 10 and 15%. Flaxseed meal did not affect the weekly body weight of broiler chicks during the first two weeks but thereafter weekly body weight reduced among flaxseed meal groups. At the end of 6^{th} week, birds fed on 15% flaxseed meal showed a reduction of 8% in body weight compared to the control group. Control group had significantly higher weight gain with slightly higher feed consumption and better feed conversion ratio (FCR), protein efficiency ratio (PER), and energy efficiency ratio (EER) than the flaxseed meal groups. Among the treatments, birds of 5 and 10% flaxseed meal groups had significantly better FCR, PER and EER compared to those of the 15% flaxseed meal group. The carcass characteristics data indicated a significant reduction in the eviscerated weight and breast yield at 15% flaxseed meal in the diet as compared to other dietary groups. However, the alpha-linolenic acid content in both breast and thigh meat was higher with an increasing level of flaxseed meal in the diets without affecting the sensory acceptability of meat. Based on the present study, up to 10% of flaxseed meal may be used in broiler diet to enhance the alpha-linolenic acid content in the broiler meat. (**Key Words :** Flaxseed Meal, Broiler, Growth Performance, Alpha-linolenic Acid)

INTRODUCTION

Flaxseed is unique among oilseeds because of its exceptionally high content of α-linolenic acid (18:3, n-3), contains 35 to 45% oil, of which 45 to 52% is α-linolenic acid (ALA, Bhatty, 1995). Traditionally, flax is crushed to produce oil for industrial applications, and the resultant flaxseed meal is used as a protein supplement in livestock feeds. In monogastric species such as poultry, the fatty acid profile of the meat and fat is directly affected by the source of fat in diet. Researches indicated that products, such as eggs and beef, from flax fed animals have increased levels of omega-3 fatty acids (Scheideler et al., 1994; Maddock et al., 2003). This has led to renewed interest in flax production and feeding flax to livestock. It has been reported that feeding omega-3 enriched diets to poultry increases the omega-3 content of eggs and meat and thus enriched poultry products offer consumers an alternative to enhance their omega-3 daily intake (Leskanich and Noble, 1997). Ajuyah et al. (1991) reported less carcass fat and larger leg along with increased omega-3 fatty acids in 10 or 20 percent flax-fed chickens. In a companion study, Ajuyah et al. (1993) observed higher levels of ALA in dark meat than white meat of broilers at 15% flaxseed level in diet as compared to meat from chickens of control group.

In India, flaxseed is generally utilized for oil extraction which goes to industrial purposes, mainly in paint industries and the residual meal is used for animal feed only. The deoiled cake is a most valuable feeding cake, good in taste and contains 36% protein with 85% digestibility (Salunke and Desai, 1986). It is fed to both milch and fattening animals. The screw pressed cake contains about 7 to 10% oil, while cake obtained from *ghani* (mechanical oil expelling unit, available in local area) may contain up to 14% fat (Salunke and Desai, 1986). The cakes from hydraulic presses have 9 to 12% oil. A typical proximate composition in flaxseed (linseed) cake is; dry matter 96.8%; protein 30.5%; fat 6.6%; nitrogen–free extract 43.2%; crude fiber 9.5%; and mineral matter 7% (Brown, 1953).

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Eastwood (2008) observed an increased α-linolenic acid content from 11 to 47 (±0.8) mg/g of back fat ($p<0.001$) and from 5 to 10 (±0.4) mg/g of loin tissue ($p<0.001$) at 15% inclusion level of dietary flaxseed meal in pig's diet. Betti et al. (2009) reported achieving 300 mg of omega-3fatty acids per 100 g of breast meat in 26.2 days at 10% ground flaxseed meal. Being a considerable source of residual oil in flaxseed meal, thus a source of omega-3 fatty acids, particularly α-linolenic acid, broilers producers can also utilize this valuable oilseed meal for production of enriched chicken meat to fulfill the demand of health conscious consumers. Keeping in view the breakthrough results in flaxseed or flaxseed meal studies, the present study was carried out to compare the effects of flaxseed meal supplementation on growth performance, proximate composition, ALA, linoleic acid (LA) content and sensory characteristics of meat in broiler chicks.

MATERIALS AND METHODS

Day- old commercial (Vencob) broiler chicks (n = 144) were randomly allocated to 4 groups in three replicates each with 12 number of chicks having equal sex ratio and they were placed in the individual floor pens. The chicks were vaccinated according to the standard procedure (Cynthia, 2005). The corn soybean meal based diets (Table 1) supplemented with 0, 5, 10 and 15% flaxseed meal (brown flaxseed (*Linum usitatissinum*), each was offered to three groups of chicks. The diets were formulated according to BIS (1992) in order to use various ingredients procured from the local market except the flaxseed meal which was freshly prepared just before conducting the study. In order to lower down the mucilage content in meal, the flaxseed meal was prepared using 30% dehulled flaxseed and 70% whole flaxseed. The oil from this flaxseed mixture was extracted in a single pass at a *ghani*. The fat and ALA content in the resultant meal was 14.97% and 40.96% (on total fatty acids basis), respectively.

The feed samples were analyzed for crude protein content (AOAC, 2000). The chicks were fed starter (12.2 MJ/kg ME, 22% CP) and finisher (12.2 MJ/kg ME, 20% CP) diets during 0-3 weeks (Phase-I), and 4-6 weeks (Phase -II) of age, respectively. Feed and fresh water were made available *ad libitum* at all times. The chicks were reared under standard conditions of housing and management in floor pens with paddy husk as litter material. The chicks were provided 23 h light and one dark hour, 95°F temperature during first week, which was reduced by 5°F during every successive week. The relative humidity of the shed was maintained to 60±5%.

Growth performance

Weekly live weight and feed intake on pen basis was recorded. The cumulated weight gain, feed conversion ratio,

Table 1. Composition of broiler diet

Basal ingredients (%)	Flaxseed meal in feed (%)							
	Phase-I (0-3 weeks)				Phase-II (4-6 weeks)			
	0	5	10	15	0	5	10	15
Corn	51.6	51.8	51.4	49.05	56.5	56	55.3	54.7
Rice polish	5	1.95	0	0	5	4	2	0
Flaxseed meal	0	5	10	15	0	5	10	15
Soybean meal	40	38.05	35.4	32.75	34.5	31.8	29.5	27.1
Vegetable oil	0.2	0	0	0	0	0	0	0
Wheat straw	0	0	0	0	0.8	0	0	0
Di-calcium phosphate	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Lime stone powder	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calculated composition								
Crude protein (%)	22.06	22.04	22.04	22.01	20.06	20.09	20.08	20.07
ME (MJ/kg)	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
Crude fat (%)	2.11	2.83	3.53	4.18	2.24	2.95	3.65	4.34
Lysine (%)	1.13	1.12	1.11	1.11	1.00	0.99	0.98	0.93
Methionine and cystine (%)	0.68	0.68	0.68	0.68	0.61	0.61	0.61	0.62
Calcium (%)	1.05	1.06	1.06	1.07	1.04	1.05	1.05	1.06
Available phosphorous (%)	0.47	0.47	0.48	0.48	0.46	0.46	0.47	0.47

Additives included (per 100 kg): Liver tonic (Superlive^{TM}) 0.25 g, Vitamin C 20 g, Choline chloride 50 g, Trace minerals 50 g (Iron, 4,000 mg; Copper, 500 mg; Manganese, 6,000 mg; Zinc, 4,600 mg; Selenium, 10 mg; Iodine 80 mg); Vitamin A, 825,000 IU; Vitamin D_3 165,000 IU Vitamin E 500 mg, Vitamin B_{12}, 0.015 mg; Vitamin K, 100 mg; Thiamine, 80 mg; Riboflavin, 6 mg; Vitamin B_6, 160 mg; Niacin, 1,200 mg; Biotin, 0.2 mg; Folic acid, 1.0 mg. In addition to these supplements, Lysine, Methionine and Cystine were also added to fulfill the requirements.

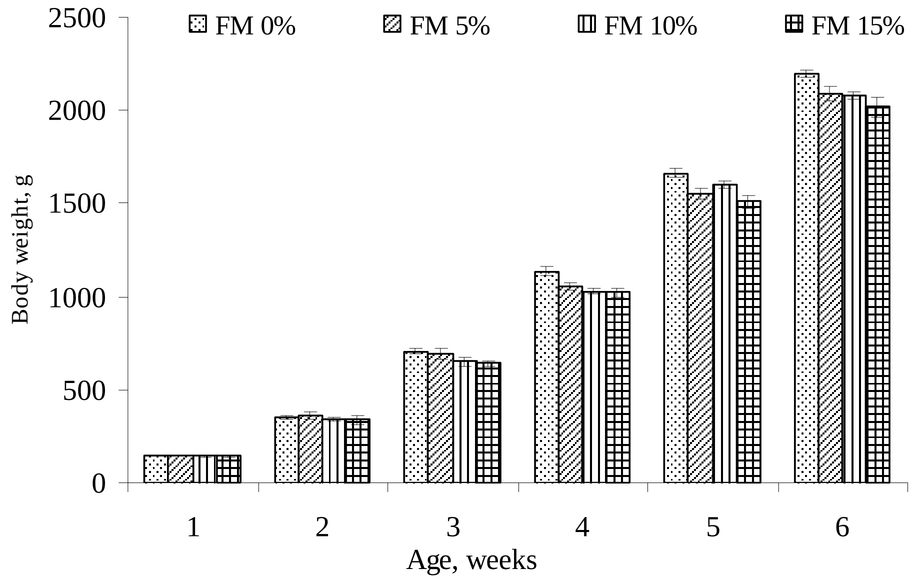

Figure 1. Effects of flaxseed meal (FM) on weekly body weight of broilers.

energy efficiency ratio (ME intake (kcal)/weight gain (g)), protein efficiency ratio (weight gain (g)/protein intake (g)) data were calculated for the entire experiment period. Mortality was recorded daily as it occurred.

Biochemical evaluation, carcass yield and organoleptic characteristics

At the end of 6 weeks of experiment, four birds (3 males and 3 females) were randomly selected from each treatment and were sacrificed to compare the carcass characteristics using the standard procedure (Richard and Rouvier, 1967). Moisture, Protein, fat, and ash content of breast and thigh meat samples were determined following the standard procedures (AOAC, 2000).

Fatty acids namely α-linolenic acid (ALA) and linoleic acid (LA) content in breast and thigh muscles were determined (Palmquist and Jenkins, 2003) by gas liquid chromatograph (NUCON GC 5765, made in India). For this analysis, total lipids were extracted from the meat sample by the method of Folch et al. (1957). Four gram of sample was weighed and homogenized thoroughly with 5 ml chloroform-methanol (2:1) solution. To the above homogenate, add 10 ml chloroform-methanol solution and transfer sample into screw capped tubes and kept overnight. Filter the sample using Whatman filter paper no. 42 into a measuring cylinder. Wash residue with 5 ml Folch solution. Note volume of solution in the measuring cylinder. Add 0.88% NaCl equivalent to the one fourth volume of the sample solution, mix thoroughly and transfer the content to separating funnel and leave it overnight. Collect chloroform layer in screw capped tubes and discard the top layer and evaporate chloroform until only oil remains in tubes. Add 1 ml methanol and 3 ml of methanol acetyl chloride (10:1) to this oil extract. Heat tubes in water bath at 85-90°C for 30 min. Then, add 8 ml of 0.88% NaCl and 3 ml of hexane into the tubes. Centrifuge at 2,000 rpm for 10 min. Collect top hexane layer and evaporate. Ethylated ester thus prepared were dissolved in 10 μl of hexane and then 1 μl was injected using micro syringe (Hamilton) in gas chromatograph (NUCON GC 5765, made in India), equipped with flame ionization detector fitted with 6% butane diol succinate (BDS) on chromosorb. The conditions for the separation were: Inlet and detector temperatures were 230 and 240°C, respectively, hydrogen flow 30 ml per minute, nitrogen flow 30 ml per minute, air flow 300-400 ml per minute. Identification of peaks was done by comparison of their retention time with those of standard fatty acyl esters. Relative concentration of fatty acid was calculated automatically by Nuchrom software.

Sensory evaluation of meat

The sensory evaluation of meat samples was done by the method of Keeton (1983). Four breast meat samples of equal dimension from each treatment were washed in running tap water and fat was removed. Samples were weighed and kept in an equal volume of 1.2% salt solution (w/v) and cooked for 10 min at 15 psi pressure in an autoclave. After removing from the autoclave, the samples were transferred to bone china plates to allow them to cool to room temperature. Sensory evaluation was made by an expert panel of nine panelists on 9 point hedonic scale with 9 for like extremely and 1 for dislike extremely. The samples were evaluated for appearance and color, flavor, tenderness, juiciness and overall acceptability. The judges had not taken any meal or beverages at least within one hour prior to this evaluation.

Statistical analysis

All the data were subjected to one-way analysis of variance (Snedecor and Cochran, 1980) with flaxseed as the main effect. Comparison among means was made by multiple range test (Duncan, 1995) at 5% significance level.

RESULTS AND DISCUSSION

The weekly body weight of broiler chicks (Table 1) indicated no significant difference among control and flaxseed meal groups during the first two weeks of the experiment. However, during third week of age, the body weight of all the treatment groups was significantly lower than control group except the group fed with 5% flaxseed meal ($p<0.05$). During fourth week of the experiment, the body weight among all the flaxseed meal groups was statistically similar but significantly lower than the control groups. At the end of 6th week, the body weight of control group was significantly higher than the flaxseed meal groups. A reduction of 8.03% in body weight was observed in the 15% flaxseed meal group than the control group at the end of 6th week of the age. Ajuyah et al. (1991) and Lee et al. (1991) also reported 4.9 to 6.7% lower body weight in broilers fed diets containing 15% flaxseed than those fed with 10% canola seed. Ajuyah et al. (1993) reported a decline of 17% in body weight of birds fed with 15% flaxseed in the diet as compared to corn soybean diet. Pekel et al. (2009) reported lower body weight of birds fed with flaxseed diets with copper supplementation. Bell and Keith (1993) also found significant reduction in average daily gain in pigs with increasing level of flaxseed meal from 0-18%.

The performance data for different age groups (Table 2) indicated that during first three weeks, there was no significant difference in weight gain among control and 5% flaxseed meal group but significant reduction of 10.27% in weight gain was observed in 15% flaxseed meal group. The weight gain was slightly improved and only 7.28% reduction was observed in 15% flaxseed meal group than the control group in the next three weeks of the experiment. The performance data during two phases of growth indicated that during first three weeks, there was no significant differences in weight gain of 5% flaxseed meal group than control however, significantly reduced weight gain was observed in 10% and 15% flaxseed meal group compared to control. This weight gain was achieved with almost same amount of feed intake and the difference in feed intake was statistically non-significant among all the treatment groups. This had resulted in statistically better FCR, PER, and EER in control and 5% flaxseed meal group compared to 10% and 15% flaxseed meal groups. During last three weeks of growth, there was significant difference

Table 2. Effect of flaxseed meal supplementation on cumulative growth performance of broiler chicks

Parameters	Level of flaxseed meal in diet (%)			
	0	5	10	15
Body weight gain, (g)				
Phase-I	662.65±15.41^{a}	646.56±28.60^{a}	605.11±21.86^{b}	594.88±12.20^{b}
Phase-II	1,487.77±14.91^{a}	1,401.27±20.99^{b}	1,430.06±38.39^{ab}	1,379.19±40.70^{b}
Overall body weight gain	2,150.42±18.17^{a}	2,047.83±37.77^{b}	2,035.17±16.56^{bc}	1,974.07±51.81^{c}
Feed Consumption (g)				
Phase -I	1,168.19±23.38	1,168.40±13.77	1,171.15±11.23	1,167.44±5.93
Phase -II	3,069.60±18.01	3,060.19±8.38	3,058.64±7.28	3,057.34±20.85
Overall feed consumption	4,237.79±20.39	4,228.59±14.74	4,229.78±17.27	4,224.77±24.87
Feed conversion ratio (FCR)				
Phase-I	1.76±0.058^{b}	1.81±0.06^{b}	1.94±0.085^{a}	1.96±0.037^{a}
Phase-II	2.06±0.030^{b}	2.18±0.027^{a}	2.14±0.057^{ba}	2.22±0.050^{a}
Overall FCR	1.97±0.007^{c}	2.07±0.031^{b}	2.08±0.015^{b}	2.14±0.043^{a}
Protein efficiency ratio (PER)				
Phase-I	2.58±0.085^{a}	2.50±0.082^{a}	2.35±0.101^{b}	2.31±0.044^{b}
Phase-II	2.42±0.035^{a}	2.28±0.029^{b}	2.33±0.063^{ab}	2.25±0.052^{b}
Overall PER	2.46±0.008^{a}	2.35±0.035^{b}	2.34±0.016^{b}	2.27±0.046^{c}
Energy efficiency ratio (EER)				
Phase-I	5.10±0.168^{b}	5.24±0.175^{b}	5.60±0.246^{a}	5.62±0.107^{a}
Phase-II	6.00±0.088^{b}	6.35±0.080^{a}	6.22±0.166^{ab}	6.44±0.146^{a}
Overall EER	5.72±0.021^{c}	6.00±0.091^{b}	6.03±0.042^{b}	6.19±0.124^{a}

Values in each cell are mean±SD; values bearing different superscripts in a row differ significantly ($p<0.05$); Phase I: 0-3 weeks; Phase II: 4-6 weeks.

in weight gain in all the treatment groups except 10% flaxseed meal group compared to control group. However, the difference was non-significant in the feed consumption in all the treatment groups compared to control. The FCR, PER and EER data of 10% flaxseed meal group was statistically similar to both control and all other flaxseed meal groups. However, the FCR, PER and EER were poorer in 5% and 15% meal groups compared to control group. During the entire experiment, control group gained significantly highest weight gain with slightly higher feed consumption than the flaxseed meal group. The overall data for FCR, PER, and EER indicated poor performance of broiler chicks in 5, 10 and 15% flaxseed meal groups. Among the treatments, birds fed 5 and 10% flaxseed meal had significantly better FCR, PER and EER compared to those fed with 15% level, which indicated that the efficiency of feed, protein and energy utilization by birds was decreased with increased inclusion level of flaxseed meal in diet. Rahimi et al. (2011) also reported the better performance of birds in terms of weight gain and FCR with the control diets than those fed with flaxseed (7.5 to 15%). Roth-Maier et al. (1998) also reported that as low as 5% of flaxseed in either ground or whole form reduced the body weight and FCR. Bond et al. (1997) concluded that flaxseed was not a practical oil source, as over 10% flaxseed in diet caused a significant performance reduction. Shen et al. (2005) also observed lower weight gain and poor feed conversion efficiency in the birds fed with flaxseed supplemented diet as compared to canola or extruded full-fat soybean based diets. Moreover, poor performance of birds fed with flaxseed based diets may also be due to the presence of anti-nutritional factor such as linatine. Klosterman et al. (1967) also reported that linatine in mucilage can decreases the productivity of animal by decreasing the amount of endogenous enzymes released from pancreas resulting in reduced digestion of feed particles. Also the non-starch polysaccharides in mucilage of flaxseed increases intestinal viscosity in monogastric animals and decreases nutrient availability (Classen and Bedford, 1991). So the lower FCR, PER and EER observed in this study may have resulted through reduction in the digestibility of feed and protein which further led to decrease in body weight.

Carcass yield and quality

The carcass characteristics data (Table 3) indicated a significant reduction in the percent eviscerated weight at 15% inclusion level of flaxseed meal as compared to other dietary groups. Although thigh percent of the carcass weight in the different treatment groups was statistically similar but significant variation in drumstick percent was observed. The breast yield was higher in the control and flaxseed meal group up to 10% level with a significant reduction in broiler fed with 15% flaxseed meal in the diet. Pekel et al. (2009) observed no beneficial effect of flaxseed supplementation on carcass weight, yield and breast weight in broiler chickens.

The moisture, protein, fat and ash content in breast and thigh meat was in the range of 74.28-74.42 and 72.88-73.02; 20.15-20.27 and 18.32-18.50; 2.34-2.51 and 4.11-4.20; 1.40-1.45 and 1.40-1.43, respectively. Results indicated that inclusion of flaxseed meal in the broiler diet had non-significant effect on protein, fat and ash content in breast and thigh tissues. However, a lower protein and higher fat content was observed in the thigh meat as compared to breast meat as also reported by Taylor et al. (2005) in broilers fed on corn soy diet. Roth-Maier et al. (1998) had found that 5 or 7.5% flaxseed, as ground or whole seed, did not affect the total lipid content in thigh tissues. Olomu and Baracos (1991) demonstrated that up to 4.5% flaxseed oil did not alter the lipid content in either white or dark muscles. However, Ajuyah et al. (1990) reported that addition of 10 or 20% of either flaxseed or flaxseed meal significantly decreased the lipid content both in white and dark meats.

The ALA content in both breast and thigh tissues was increased significantly with increasing level of flaxseed meal in broiler's diet (Table 4). Different levels of flaxseed meal in the diet also reduced the linoleic acid both in breast and thigh meat. Although the total ALA in thigh tissues

Table 3. Effect of flaxseed meal supplementation on carcass characteristics of broiler chicks

Parameters	Level of flaxseed meal in diet (%)			
	0	5	10	15
Eviscerated (%)	61.15±0.54[a]	60.80±0.55[a]	60.79±0.81[a]	59.15±0.95[b]
Giblet (%)	4.74±0.16	4.72±0.12	4.73±0.06	4.71±0.05
Breast (%)	31.45±1.12[a]	30.06±0.75[ab]	31.25±1.20[a]	29.30±0.66[b]
Drumstick (%)	13.92±0.59[c]	15.22±0.32[a]	14.19±0.44[bc]	14.84±0.33[ab]
Thigh (%)	15.67±0.75	16.00±0.95	15.71±1.27	15.73±0.56
Edible (%)	65.89±0.69[a]	65.51±0.59[a]	65.52±0.85[a]	63.86±0.92[b]
Offal parts (%)	34.11±0.69[b]	34.49±0.59[b]	34.48±0.85[b]	36.14±0.92[a]

Values in each cell are mean±SD; values bearing different superscripts in a row differ significantly ($p<0.05$).

Table 4. Effect of flaxseed meal supplementation on meat quality of broiler chicks

Parameters	Level of flaxseed meal in diet (%)			
	0	5	10	15
ALA and LA content in broiler meat				
Breast meat				
ALA (% on total fatty acids)	2.02±1.03[d]	4.92±1.04[c]	9.54±0.57[b]	12.26±0.83[a]
LA (% on total fatty acids)	38.77±0.76[a]	38.00±1.18[ab]	35.78±1.32[b]	32.97±1.61[c]
Thigh meat				
ALA (% on total fatty acids)	3.06±0.40[c]	4.54±1.70[c]	9.73±0.57[b]	12.12±0.73[a]
LA (% on total fatty acids)	38.53±1.15[a]	37.12±1.32[ab]	36.02±1.13[b]	33.66±1.06[c]
Sensory characteristics				
Appearance and colour	7.79±0.49	7.14±0.48	7.64±0.48	7.57±0.79
Tenderness	7.29±0.49	7.57±0.61	7.79±0.57	7.79±0.70
Juiciness	7.21±0.39	7.36±0.56	7.57±0.67	7.50±0.50
Flavour	7.29±0.57	7.64±0.75	7.36±0.48	7.29±0.49
Overall acceptability	7.26±0.53	7.36±0.42	7.57±0.53	7.51±0.57

Values in each cell are mean±SD; values bearing different superscripts in a row differ significantly ($p<0.05$).
ALA = Alpha-linolenic acid; LA = Linoleic acid.

seems to be on higher side, might be due to higher fat content in these tissue than breast meat but the ALA content on % fatty acid basis is almost similar in both of them. Kelempekoglou et al. (2009) also reported non-significant difference in the distribution of ALA content between thighs and breast tissues. Betti et al. (2009) reported achieving 300 mg of omega-3fatty acids per 100 g of breast meat in 26.2 days at 10% ground whole flaxseed meal in broilers diet, which is a requirement for labeling the meat as a source of omega-3 fatty acids (Canadian Food Inspection Agency, 2003). Other studies had (Ajuyah et al., 1993; Rahimi et al., 2011; Shen et al., 2005) also reported that the response of fatty acid profile of tissue to dietary flaxseed inclusion follows a proportional pattern that reflects dosage and period of dietary flaxseed treatment.

Organoleptic properties of breast meat from all the treatment groups indicated no significant difference in the mean scores for colour and flavor (Table 4). Although statistically similar but mean sensory scores for tenderness and juiciness were slightly better in treatment groups than the control group. The overall acceptability scores for breast meat from all the treatments ranged from 7.26 in control to 7.57 in 10% flaxseed meal groups but the difference were statistically non-significant. Statistically similar mean overall acceptability scores for all the treatment groups showed that flaxseed meal supplementation did not affect the organoleptic quality of meat.

It is concluded that with increasing level of flaxseed meal in broiler's diet, reduction in growth performance in terms of poor weight gain has been observed maximum to the level of 8.2% at 15% inclusion level of flaxseed meal. But carcass traits expressed no significant difference in terms of the eviscerated weight and breast yield. However, the alpha-linolenic acid content in both breast and thigh meat was higher with increasing level of flaxseed meal in the diets. Therefore, taking into account the higher growth retardation at 15% flaxseed meal in the diet, 10% of flaxseed meal can be used in the diets to enable designing of fatty acid profiles especially omega-3 fatty acid in terms of alpha-linolenic acid content in the lipid of muscular tissue, without losing much in terms of weight gain.

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