Forage Res., **43** (2) : pp. 145-150 (2017) **http://forageresearch.in**

EFFECTS OF LINSEED OIL FEEDING ON CARCASS TRAITS AND MEAT COMPOSITION IN BROILER CHICKENS

JYOTI SHUNTHWAL*, SAJJAN SIHAG, MADHU SUDAN GURAY AND NANCY SHEORAN

Department of Animal Nutrition, College of Veterinary Sciences,
LLR University of Veterinary and Animal Sciences,
Hisar-125004, Haryana, India
**(e-mail : jyotishunthwal.112@gmail.com)*

(Received : 5 September 2017; Accepted : 25 September 2017)

SUMMARY

A study was carried out in the Department of Animal Nutrition at LUVAS, Hisar, in the year 2015. This study was aimed to investigate the effect of replacing sunflower oil with linseed oil on carcass traits and meat quality of broiler chickens. A total of 300 day-old commercial broiler chicks were procured and randomly distributed into five treatments, each treatment had six replicates with ten chicks in each. Growth trial of 6 weeks was conducted in a complete randomized design comprising five dietary treatment groups. The control group (T_1) was on basal diet with sunflower oil as per BIS 2007 specification, while T_2, T_3, T_4 and T_5 were fed with linseed oil replacing sunflower oil of control group @ 25, 50, 75 and 100%, respectively. Treatment groups with linseed oil had no significant effect on dressing percentage and eviscerated yield compared to control group. Giblet percentage of all dietary treatments with linseed oil was significantly lower ($P<0.05$) than the control group. Moisture and crude protein of the breast and thigh muscle were not affected by inclusion of different levels of linseed oil. Whereas, the fat content of breast muscle with 50, 75 and 100%; and of thigh muscle with 75 and 100% linseed oil supplementation was significantly lower ($P<0.05$) than the control group. Result showed significant ($P<0.05$) difference in saturated fatty acid (SFA) and Poly unsaturated fatty acid (PUFA) content of breast and thigh muscle as compared to the control group. The SFA (palmitic acid and stearic acid) content of thigh muscle in dietary treatment group with 75 and 100% replacement with linseed oil decreased significantly ($P<0.05$) as compared to control group. However, the SFA content of breast muscle in each level of linseed oil decreased significantly ($P<0.05$) as compared to control group. Mono unsaturated fatty acid (MUFA), the oleic acid decreased ($P<0.05$) in group having linseed oil at the level of 50,75 and 100% as compared to control group in both muscles. The n-6 PUFA linoleic acid and arachidonic acid content in both breast and thigh muscles decreased at the level of 50, 75 and 100% sunflower oil replacement with linseed oil than the control group. The n-3 PUFA linolenic acid content increased significantly ($P<0.05$) in all groups with different linseed oil (25, 50, 75 and 100%) levels as compared to the sunflower oil group. A significant increase in poly-unsaturated FA (PUFA), n-3 FA and a significant decrease in n-6:n-3 were noticed in breast and thigh muscle due to dietary incorporation of linseed oil in the diets, the effect being more pronounced at the highest level of supplementation. The results of study inferred that supplementation of linseed oil in ration of broilers improves the quality of meat in terms of increased n-3 PUFA proportion with lean meat production which is beneficial for human health.

Key words : Linseed oil, broiler, breast, thigh, saturated fatty acid, poly unsaturated fatty acid, mono unsaturated fatty acid

It has been shown that consumers prefer poultry meat and its products for several reasons. Fats in poultry diets constitute the basic nutrient and fulfill a number of significant functions in the body. The addition of lipid sources to diets is one option that can improve the birds' performance due to the high energy density and high metabolisable energy of oils, which can also confer better palatability to the feed. The beneficial health effects of dietary omega-3 (n-3) polyunsaturated fatty acids (PUFA) have been well documented and emphasise the importance of increasing the consumption of these fatty acid in human diet. The main reason for incorporating linseed oil in mixtures for broiler chicken is favourable effect of polyunsaturated fatty acid (PUFA) on animal and human health. The first effect of adding linseed oil is a high increase in ?-linolenic acid content and a possible increase in other n3 PUFA (Zelenka *et al.*, 2008). There is increasing recognition of the health benefits of PUFA in general, and of n3 fatty acids in

particular, because these fatty acids are essential for humans. Several studies have shown that the utilization of oils rich in polyunsaturated fatty acids (PUFAs), such as sunflower and flaxseed oils , improves broiler performance compared to animal fats and oils rich in monounsaturated fatty acids (e.g. palm and olive). The presence of balanced omega-6: omega-3 fatty acids in poultry diets are essential for normal growth and development and other biological functions (FAO, 2010). Mostly broiler diets include high level of n-6 fatty acids in their fat sources, which directly affects the omega-6:omega-3 fatty acids ratio. Omega-3 (PUFAs) is essential for playing important role in the prevention of coronary heart disease, hypertension, inflammatory, autoimmune disorders and cancer in human being. Wang et al. (2013) observed that feeding laying chickens diets rich in n-3 PUFA promoted the growth of the thymus, spleen, and bursa up to 4 wk of age. Dietary fatty acids are absorbed by monogastric animals and deposited in their tissues, n-6 and n-3 PUFAs are competitively metabolized by the same pathway (Luo *et al.* 2009). So, there is a huge potential in manipulation of the fatty acid profiles of poultry tissue through diets. Dietary fat addition enhances the performance of broilers in terms of body composition and meat characteristics. 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. Feeding oil rich in omega-3 fatty acid also improve the quality of egg yolk by improving its n-3 fatty acid concentration (Nanjappan *et al.* 2013)

Flaxseed is rich in omega-3 polyunsaturated fatty acids (PUFA), alpha linolenic acid (ALA). ALA constitutes about 57% of the total fatty acids in flaxseed, making flaxseed one of the richest natural sources of ALA. Therefore, the present investigation was carried out to study the effect of linseed oil supplementation on meat quantity and quality parameters in broiler chicken.

MATERIALS AND METHODS

The present investigation was carried out in the Department of Animal Nutrition at LUVAS, Hisar, in the year 2015, with feeding trial period of 45 days. Three hundred day-old commercial broiler chicks were procured and randomly distributed into five treatment groups viz. T_1, T_2, T_3, T_4 and T_5 with six replicates of ten chicks in each. All the chicks were offered with starter ration from 0 to 21 days and finisher ration from 22 to 42 days of age as per BIS (2007) specifications. The experimental diets (Table 1) were formulated to meet the nutrient recommendations (BIS, 2007). The Chemical composition (%DM basis) and metabolizable energy of starter and finisher diet are given in table.1 and 2. The control group (T_1) was offered basal diet having sunflower oil. While chicks in treatment groups T_2, T_3, T_4 and T_5, in the basal diet sunflower oil was replaced with linseed oil @ 25, 50, 75 and 100%, respectively. The chicks were kept hygienically on floor litter system in well ventilated separate pens. All the birds were reared adopting uniform management conditions. The chicks were brooded at 35°C during the first week. The birds were vaccinated against prevailing diseases adopting a standard protocol. The birds were constantly observed for any kind of stress or different behavior from normal one. At the end of the experiment, one bird from each replicate was slaughtered ethically by mechanical stunning followed by exsanguinations and thigh and breast muscle sample were collected. Samples of breast and thigh muscles were taken from each of the slaughtered birds and stored in deep-freeze separately for further analysis. These samples were analyzed for moisture; protein and ether extract as per AOAC (2007). For carcass evaluations, immediately after

TABLE 1
Ingredient (%) and chemical composition (% DM basis) of basal diet

Feed ingredient	Starter diet	Finisher diet
Maize (kg)	53	57
Soybean meal (kg)	19	16
Ground nut cake (kg)	12	11
Rice police (kg)	3	4
Fish meal (kg)	7	5
*Sunflower oil (kg)	4	5
Mineral mixture (kg)	2.0	2.0
**Feed additives (kg)	0.29	0.29
Chemical composition (% DM basis)		
Crude protein %	22.04	20.04
Crude fibre %	3.61	3.29
Ether extract %	8.90	8.91
Total ash %	5.66	5.84
***Metabolizable energy (Kcal/kg)	3056	3163

* In T_2, T_3, T_4 and T_5, treatment groups sunflower oil was replaced with linseed oil @ 25, 50, 75 and 100%, respectively, in starter and finisher diets.

** Feed additives include Vitamin Mixture-I-10 g, Vitamin, Amino acid and Ca mixture-II 20 g, Coccidiostat (Dinitro-0-Toluamide)-50 g, Choline chloride-50 g, Lysine-50 g, DL-methionine-80 g and Chlortetracycline -33.5g/100kg

*** Calculated values - BIS (2007).

recording their live weights, the birds were killed by severing the jugular vein and allowed to bleed completely following 'Halal' method. Dressed weight was calculated by deducting blood, feathers, head, shank and skin losses from live weight. Dressing percentage was calculated as: Dressed weight/Live weight× 100. The eviscerated and drawn weights were recorded and eviscerated was calculated as: Dressed weight – weight of viscera. Also eviscerated percentage as Eviscerated weight/ Live weight× 100. Separate weights of liver, gizzard, heart, abdominal fat were also recorded. Total lipids from samples of breast and thigh muscles were extracted according to the method of Angelo *et al.* (1987). After that methyl esters were prepared by the method of Luddy *et al.* (1968). Methyl esters of fatty acids were separated in a Nucon-5765 gas chromatograph equipped with flame ionization detector. Stainless steel column (10"×1/8") was packed with 20% diethylene glycol succinate (DEGS) on 60-80 mesh chromosorb-W. The column temperature was 190^0 C and the flow of the nitrogen carrier gas was maintained at 35 ml/minute. The peak was identified by comparison of its retention time with that of standard fatty acid. The area under peak was calculated by triangulation and converted directly into relative percentage.

The data were analyzed using general linear model procedure of statistical package for social sciences 20th version (SPSS) and comparison of means tested using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

The results of the study unveiled that moisture and crude protein contents in both breast and thigh muscles between different dietary treatment groups did not differ significantly, indicating that supplementation of linseed oil in place of sunflower oil in the diet of broiler chicken is nutritionally balanced in terms of amino acids and has no effect on protein and moisture content of meat, (Table 2). However, ether extract content of breast muscle of chicken of dietary treatment groups T_3 (50 %,), T_4 (75%) and T_5 (100%) were significantly (P<0.5) less as compared to T_1 (control) and T_2 (25%). It was also found that ether extract content of thigh muscle in broilers fed 75 and 100 % linseed seed supplemented diet were significantly (P<0.05) lower as compared to other groups which among themselves did not vary statistically. These results are in agreement with Mridula *et al.* (2015) who reported that the protein, fat and ash content of breast and thigh meat samples in broilers fed different levels (@ 2.5%, 5% and 7.5%) of flaxseed in the diet did not differ significantly. Similarly Ebied *et al.* (2011) observed no significant differences in the content of dry matter, crude protein and ash in meat of broilers fed 10 g of linseed oil per kg diet. Lopes *et al.* (2013) also informed that in broilers the substitution of soyabean oil with flaxseed oil had no effect on the breast and drumstick meat chemical composition, except for the thigh fat quantity, which was reduced significantly (P<0.05).

Fatty acid composition of breast and thigh muscle of dietary treatment upto 100% linseed oil significantly (P<0.05) differed from the control group (sunflower oil) (Table3.). Saturated fatty acid i.e. palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$) content of thigh muscle of dietary group with 75% and 100% replacement of sunflower oil with linseed oil decreased significantly (P<0.05) than control group, whereas in breast muscle in all dietary group upto 100% replacement of sunflower oil with linseed oil the saturated fatty acid content decreased significantly (P<0.05) as compared to control group. PUFA n-6 linoleic acid of breast and in thigh muscle decreased

TABLE 2
Composition (%) of breast and thigh muscles in experimental birds under different dietary treatments

Treatment	Breast muscles			Thigh muscles		
	Moisture	Crude protein	Ether extract	Moisture	Crude protein	Ether extract
T_1	70.88±0.30	22.59±0.14	6.24^{b}±0.05	70.34±0.21	22.10±0.17	7.42^{b}±0.12
T_2	70.57±0.05	22.22±0.13	6.22^{ab}±0.04	70.40±0.09	22.05±0.12	7.39^{b}±0.0
T_3	70.59±0.15	22.40±0.09	6.14^{a}±0.04	70.34±0.22	22.06±0.14	7.31^{ab}±0.09
T_4	70.70±0.20	22.79±0.36	6.14^{a}±0.01	70.39±0.10	22.04±0.27	7.19^{a}±0.01
T_5	70.42±0.05	22.52±0.06	6.10^{a}±0.02	70.34±0.08	22.03±0.18	7.12^{a}±0.01

Values bearing different superscripts in a column differ significantly (P<0.05).

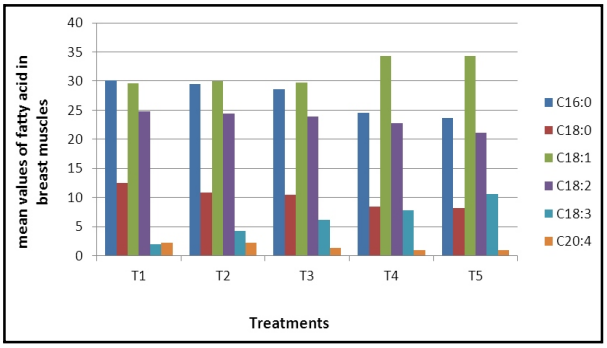

Fig. 1. Mean values of fatty acid percentage of breast muscle under different dietary treatments.

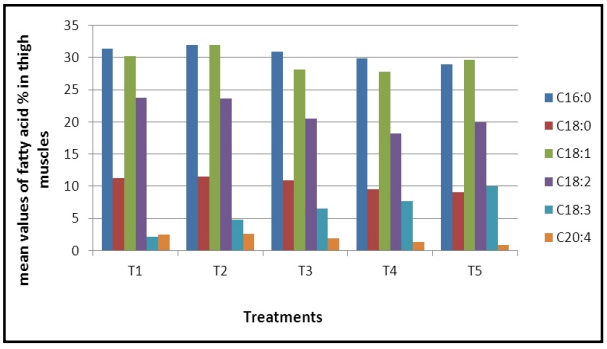

Fig. 2. Mean values of fatty acid percentage of thigh muscle under different dietary treatments.

significantly (P<0.05) in all dietary groups T_3, T_4 and T_5 having 50%, 75% and 100% linseed oil supplementation as compared to control group T_1. In breast muscle T_3, T_4 and T_5 treatment group showed significantly (P<0.05) decreased n-9 MUFA, oliec ($C_{18:1}$) content as compared to control group, whereas in thigh muscle decreased (P<0.05) in all linseed oil group as compared to control group. PUFA n-3 (ALA) content of thigh as well as breast muscle increased significantly in all treatment group upto 100% replacement with linseed oil than control group(0% linseed oil). In linseed, PUFA made up over 70% of total FA, the proportion of n-6/n-3 PUFA was 0.28. These results may explained due to high content of PUFA mainly n-3 ALA content and comparative lower concentration of n-6 linoleic acid content in linseed oil. PUFA n-6 arachidonic fatty acid content in both breast and thigh muscle of dietary group containing 50%, 75% and 100% replacement with linseed oil reduced significantly (P<0.05) as compared to the control group. Similar results were reported by Stana?ev *et al.* (2014) that the inclusion of flaxseed oil in the diet of chickens in amount of 4% and 8% had a generally high effect on n-3 PUFA deposition during different stages of the broiler's life. It has been found that the flaxseed oil is an excellent source of polyunsaturated fatty acids of the n-3 family, which can be very efficiently converted from phospholipids in tissues lipids of poultry (Lopez-Ferrer *et al. 2001*). Similarly Zelenka *et al.* (2008) also concluded that with the exception of docosahexaenoic acid (C22:6n-3; DHA), the content of all n-3 PUFA was significantly higher ($P < 0.001$) in thigh muscle than in breast muscle. Similarly, Ebeid *et al.* (2011) also showed that feeding 2% Fish oil, 2% Linseed oil or a mixture of 1% Fish oil +1% Linseed oil to birds resulted in a proportional increase in the total n-3 PUFA concentrations (P ? 0.01) in meat lipids, as compared with the other treatments.

TABLE 3
Fatty acid percentage of breast muscle under different dietary treatments

Treatments	Fatty Acids (%)					
	C16 : 0	C18 : 0	C18 : 1	C18 : 2	C18 : 3	C20 : 4
			Breast muscle			
T_1	$30.13^{e}\pm0.10$	$12.45^{c}\pm0.18$	$34.26^{b}\pm0.09$	$24.84^{d}\pm0.16$	$1.99^{a}\pm0.02$	$2.19^{c}\pm0.08$
T_2	$29.43^{d}\pm0.24$	$10.87^{b}\pm0.12$	$34.36^{b}\pm0.37$	$24.43^{cd}\pm0.15$	$4.26^{b}\pm0.11$	$2.17^{c}\pm0.13$
T_3	$28.55^{c}\pm0.26$	$10.41^{b}\pm0.14$	$29.67^{a}\pm0.13$	$23.89^{c}\pm0.28$	$6.15^{c}\pm0.13$	$1.30^{b}\pm0.12$
T_4	$24.53^{b}\pm0.21$	$8.38^{a}\pm0.314$	$30.02^{a}\pm0.13$	$22.71^{b}\pm0.22$	$7.85^{d}\pm0.24$	$0.99^{a}\pm0.05$
T_5	$23.70^{a}\pm0.13$	$8.18^{a}\pm0.21$	$29.71^{a}\pm0.14$	$21.13^{a}\pm0.21$	$10.54^{e}\pm0.16$	$0.92^{a}\pm0.04$
			Thigh muscle			
T_1	$31.31^{cd}\pm0.17$	$11.23^{bc}\pm0.23$	$31.97^{d}\pm0.23$	$23.71^{c}\pm0.17$	$2.12^{a}\pm.13$	$2.47^{d}\pm0.35$
T_2	$30.90^{c}\pm0.34$	$11.53^{c}\pm0.23$	$30.17^{c}\pm0.17$	$23.64^{c}\pm0.27$	$4.81^{b}\pm0.22$	$2.58^{d}\pm0.54$
T_3	$31.89^{d}\pm0.20$	$10.97^{b}\pm0.07$	$28.16^{a}\pm0.34$	$20.55^{b}\pm0.36$	$6.53^{c}\pm0.19$	$1.91^{c}\pm0.04$
T_4	$29.87^{b}\pm0.26$	$9.51^{a}\pm0.10$	$27.82^{a}\pm0.44$	$18.21^{a}\pm0.11$	$7.72^{d}\pm0.21$	$1.30^{b}\pm0.05$
T_5	$28.93^{a}\pm0.28$	$9.05^{a}\pm0.17$	$29.64^{b}\pm0.31$	$19.97^{b}\pm0.18$	$9.94^{e}\pm0.07$	$0.92^{a}\pm0.06$

Values bearing different superscripts in a column differ significantly (P<0.05).

TABLE 4
Dressed, eviscerated and weight of giblets of the experimental birds under different dietary treatments

Treatment	Dressed (%)	Eviscerated (%)	Liver (%)	Heart (%)	Gizzard (%)	Giblet (%)	Abdominal fat (%)	Kidney (%)
T_1	70.57± 0.74	60.89± 0.64	1.76^{b}± 0.12	0.56± 0.04	2.35± 0.13	5.13^{b}± 0.15	2.36^{c}± 0.05	0.10^{a}± 0.004
T_2	70.70± 0.44	59.34± 0.41	1.49^{ab}± 0.03	0.53± 0.05	2.34± 0.11	4.40^{a}± 0.21	2.19^{b}± 0.05	0.12^{b}± 0.01
T_3	70.50± 1.52	59.38± 1.56	1.65^{b}± 0.13	0.47± 0.03	2.00± 0.09	4.12^{a}± 0.06	2.18^{b}± 0.07	0.11^{ab}± 0.00
T_4	70.10± 1.77	60.06± 1.81	1.34^{a}± 0.07	0.48± 0.03	2.21± 0.12	4.11^{a}± 0.19	1.92^{a}± 0.02	0.11^{ab}± 0.00
T_5	70.03± 0.91	60.78± 0.93	1.52^{ab}± 0.04	0.52± 0.04	2.20± 0.1	4.41^{a}± 0.18	1.86^{a}± 0.02	0.10^{a}± 0.00

Values bearing different superscripts in a column differ significantly (P<0.05).

The differences in dressing percentage of treatment groupsT_1, T_2, T_3, T_4 and T_5 (0%, 25%, 50%, 75% and 100% respectively) were non-significant (Table. 4). The dietary treatment groups T_2, T_3, T_4 and T_5 had statistically similar eviscerated mass yield compared to the control. These results are in agreement with those reported by Panda *et al. (*2015). The carcass parameters such as dressed weight, liver, giblet and breast meat yield were not affected due to dietary incorporation of linseed oil in the diet. However, the abdominal fat content reduced significantly by dietary inclusions. Similarly, Mridula *et al*. (2015) concluded that the carcass characteristics indicated not much of a difference in the evisceration rate and giblet among treatment groups. Similarly Arshami *et al*. (2010) also stated the non-significant results for breast weight per cent between treatment (flaxseed 5–10%) and control group with the trend of 5% > 10% > 7.5% > 0.0% flaxseed in the diet. These result may attributed to isocaloric diet, equal feed intake by all birds of all groups. Linseed oil was not showing any harmful effect on carcass traits at all level.

CONCLUSION

The results of investigation revealed that supplementation of linseed oil in place of sunflower oil in the diet of broiler chicken had no effect on moisture and protein content of breast and thigh muscles , however, lean meat is produced having low fat content. Linseed oil being rich in omega-3 ALA content as compared to sunflower oil had improved the quality and fatty acid profile of meat with high n-3 and low n-6 PUFA having appropriate ratio of polyunsaturated acid which is beneficial for human as well animal health. Also There was no effect of replacing sunflower oil with linseed oil up to 100% on the carcass traits, however, SFA (saturated fatty acid) content were decreased in breast and thigh muscles of broiler chickens. Thus it may inferred that addition of linseed oil in dietary regimen of broilers improves meat quality.

REFERENCES

Angelo, St. A.J., J.R. Vercellotti, , M.G. Legendre, C.H. Vinnett, J.W. Kuan, C. James, and H.P. Dupuy. 1987 : Chemical and instrumental analysis of warmed over flavor in beef. *J. Food Sci.*, **52**: 1163-1166.

Arshami, J., and M. Pilevar. 2010 : Effects of long-term feeding flaxseed on growth and carcass parameters, ovarian morphology and egg production of pullets. *International J. Poult. Sci*., **9**.

Association of official analytical chemists (AOAC). 2007 : Official methods of analysis.18th ed. Gaithersburg, Madison.

BIS. 2007: Requirement for chicken feeds. IS: 1374-2007 : Manak Bhawan, 9 Bahadurshah Zafar Marg, New Delhi – 110001.

Duncan, D.B. 1955 : Multiple range and multiple *F* tests. *Biometrics*, **11**: 1-42.

Ebeid, T., A. Fayoud, S. A. El-Soud, Y. Eid, and M. El-Habbak. 2011 : The effect of omega-3 enriched meat production on lipid peroxidation, antioxidative status, immune response and tibia bone characteristics in Japanese quail. *Czech J. Ani. Sci.* **56**: 314-324.

FAO. 2012 : Food and Agriculture Organization of the United Nations. Available: https://www.fao.org.br/download/ Oecdfao_AgriculturalOutlook 20102019.pdf. Accessed 22 April 2012.

Lopes, DC.N., E. G. Xavier, V. L. Santos, F. M. Gonçalves, M. A. Anciuti, V. F. B. Roll, and A. A. S. Catalan.

2013 : Growth performance, carcass traits, meat chemical composition and blood serum metabolites of broiler chicken fed on diets containing flaxseed oil. *British Poult. Sci*., **54**: 780-788.

Lopez-Ferrer, S., M.D. Baucells, A.C. Barroeta, J. Galobart, and M. A. Grashorn. 2001 : n-3 Enrichment of chicken meat. 2. Use of precursors of long-chain polyunsaturated fatty acids: Linseed oil. *Poult. Sci.,* **80**: 753-761.

Luddy, F.E., R.A. Barford, S.F. Herb, and P. Magdman. 1968: A rapid and quantitative procedure for the preparation of methyl esters of butteroil and other fats.*J. American Oil Chemists Society*. **45**(8): 549-552.

Luo, H.F., H.K. Wei, F.R. Huang, Z. Zhou, S.W. Jiang, and J. Peng. 2009 : The effect of linseed on intramuscular fat content and adipogenesis related genes in skeletal muscle of pigs. *Lipids.* **44**: 999–1010.

Mridula, D., D. Kaur, S.S. Nagra, P. Barnwal, S. Gurumayum, and K. K. Singh. 2014 : Growth performance and quality characteristics of flaxseed-fed broiler chicks. *J. Appl. Anim. Res*., **43**: 345-351.

Selvaraj, P., K. Nanjappan, S. Jayachandran, P. Visha, K. Yamuna, D. Chandrasekaran, and R. Mathivanan. 2013: Enriching Chicken Eggs with Omega-3 Fatty Acids for Improving Human Health. *Indian J. Anim. Sci*. **83**

Panda, A., K. Sridhar, G. Lavanya, B. Prakash, S.R. Rao, and, M. Raju. 2015. Growth performance, carcass characteristics, fatty acid composition and sensory attributes of meat of broiler chickens fed diet incorporated with linseed oil. *Indian J. Anim. Sci*., **85**: 1354-1357.

Stana?ev, V. •., N. Miloševi?, Z. Pavlovski, D. Mili?, M. Vuki?-Vranješ, N. Puva?a, and V. S. Stana?ev. 2014 : Effects of dietary soybean, flaxseed and rapeseed oil addition on broilers meat quality. *Biotech. Anim. Husb.,* **30**(4) : 677-685.

Wang, J., Q. Zhu, H. Ahmad, X. Zhang, and T. Wang. 2013 : Combination of Linseed and Palm Oils is a Better Alternative than Single Oil for Broilers Exposed to High Environmental Temperature. *J. Poult. Sci.*, **50** : 332-339.

Zelenka, J., D. Schneiderova, E. Mrkvicova, and P. Dolezal. 2008 : The effect of dietary linseed oils with different fatty acid pattern on the content of fatty acids in chicken meat. *Veterinarni Medicina-Praha***. 53**: 77.