

# Effects of various n-3 lipid sources on the quality characteristics and fatty acids composition of chicken meat

S. EZHIL VALAVAN<sup>1\*</sup>, P.SELVARAJ, B.MOHAN, T.K.SUNDARAM, K.VISWANATHAN, R.RAVI and M.R.PURUSHOTHAMAN

<sup>1</sup>Assistant Professor, Distance Education Cell, Directorate of Extension Education, Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu, India - 600 051.

\*Corresponding author: vet\_ezhil2001@yahoo.co.in

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The present study was undertaken at Centre of Advanced Studies in Poultry Science, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India. Broiler biological experiment was conducted to study the effect of various n-3 lipid sources independently and simultaneously (at one, two and three per cent levels) in broiler ration from day old chick to 7 weeks of age. Fish, linseed and rapeseed oils were used as n-3 lipid sources to enrich n-3 fatty acids in chicken meat. Fish oil recorded the higher value of myristic, palmitic and stearic acids, Eicosapentaenoic acid (EPA), Docosahexaenoic acid (DHA) and n-3 / n-6 fatty acids ratio while linseed oil recorded the higher amount of oleic, linolenic and total n-3 fatty acids. However, linoleic, oleic and erucic acids were higher in rapeseed oil utilised in this study. The inclusion of n-3 lipid sources in broiler ration had no adverse effect on livability, ready – to – cook and giblets yields, meat quality in terms of organoleptic assessment such as appearance, juiciness, flavour, tenderness and overall acceptability scores. The broiler body weight gain, feed consumption and abdominal fat percentage showed a significant ( $P<0.01$ ) reduction due to n-3 lipid sources supplementation in broiler diet. The supplementation of n-3 lipid sources in broiler ration had significant ( $P<0.01$ ) increase on n-3 fatty acids composition such as linolenic acid, EPA, DHA, total n-3 fatty acids, total n-6 fatty acids and total n-3 / n-6 fatty acids ratio of broiler meat and a significant reduction ( $p<0.01$ ) in palmitic and stearic acid concentrations. The total unsaturated fatty acids concentration in breast and thigh meat of broilers showed an increase in all the treated groups due to incorporation of various n-3 lipid sources in feed. Feeding broilers with one per cent linseed oil in diet from zero to seven weeks of age were found to be advantageous in terms of net profit.

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**Key Words:** n-3 lipid sources; production performances; fatty acids composition of broiler meat.

## Introduction

Due to increased literacy levels, consumers have become health conscious and want to consume only healthy foods. Therefore in many countries manufacturers have started producing health-promoting foods. In this context, foods enriched with n-3 fatty acids are gaining popularity because, these fatty acids have been reported to protect against cardiovascular and inflammatory diseases, certain types of cancer (Kinsella *et al.*, 1990), decreases plasma triglycerides, blood pressure, platelet aggregation, thrombosis

and atherosclerosis particularly in diabetics and they also provide essential nutrients required for brain and visual development in children and enhance immunity in adults.

Though fish, linseed and algae are rich sources of omega -3 fatty acids, many people are not consuming them due to various reasons. Hence, it is right time to engineer commonly consumed foods with beneficial components especially n-3 fatty acids. It is needless to say, chicken meat play an important role in day- to-day human diets. The poultry has a peculiar capability of incorporating not only these omega -3 fatty acids but also anti - oxidants and immuno-modulators. Hence, a maiden attempt was made to engineer designer chicken meat by manipulating the fatty acids composition of meat by altering their dietary rations.

## Materials and Methods

The broiler biological experiment was started using two hundred and seventy three commercial day old broiler chicks. The chicks were obtained from a local commercial broiler hatchery. Broiler chicks were weighed, wing banded and randomly allotted to thirteen treatment groups with three replicates having seven broiler chicks each. n-3 lipid sources such as fish, linseed and rapeseed oils were incorporated into broiler (starter and finisher) basal diets formulated as per the standard prescribed by BIS (1992) at the graded levels either independently or simultaneously and thus the experimental diets were prepared and formed thirteen treatment groups (Table.1). All the diets were made isonitrogenous and

**Table 1.**

**Treatment groups and experimental diets of broilers**

T <sub>1</sub> Basal feed (control)			
T <sub>2</sub>	Basal feed + Fish oil (FO) 1%	T <sub>8</sub>	Basal feed + FO 3%
T <sub>3</sub>	Basal feed + Linseed oil (LO)1%	T <sub>9</sub>	Basal feed + LO 3%
T <sub>4</sub>	Basal feed + Rapeseed oil (RO)1%	T <sub>10</sub>	Basal feed + RO 3%
T <sub>5</sub>	Basal feed + FO 2%	T <sub>11</sub>	Basal feed + (FO +LO+RO) 1%
T <sub>6</sub>	Basal feed + LO 2%	T <sub>12</sub>	Basal feed + (FO +LO+RO) 2%
T <sub>7</sub>	Basal feed + RO 2%	T <sub>13</sub>	Basal feed + (FO +LO+RO) 3%

isocaloric by adjusting the other ingredients. Broiler chicks of all treatments were reared in cage system of management with standard managerial practices throughout the experimental period (7 weeks) except for the variation of n-3 lipid sources used in feed. The birds were fed with experimental diet *ad libitum* up to 7 weeks of age.

Individual body weight and total feed consumption of birds in each group was recorded at weekly intervals to calculate the weight gain and feed efficiency. Any occurrence of mortality during the experimental period was recorded and the livability percentage was worked out. At the end of the seventh week birds were slaughtered (Arumugam and Panda, 1970), the carcass yield including the giblets was calculated on the slaughter weight basis and recorded as ready - to - cook yield. The breast and thigh meat samples were collected from each carcass and stored at -20<sup>0</sup> C for the estimation of fatty acid composition and sensory evaluation to assess the meat quality. The organoleptic assessment of meat samples was recorded on a nine point hedonic scale with ascending ratings for the desired attributes of appearance, flavour, juiciness, tenderness and overall acceptability (Panda *et al.*, 1982).

Before starting the biological experiment, n-3 lipid sources (Fish, linseed and rapeseed oils) were subjected to fatty acid estimation. The lipid content was extracted and transmethylated as per the method described by Sukhija and Palmquist (1988). Two grams each of fish, linseed and rapeseed oils were weighed into separate test tubes, 10 volumes of Folch-I solution (containing chloroform methanol 2:1vol/vol) (Folch *et al.*, 1957) was added and homogenized for 10 seconds at high speed. Twenty-five micrograms of butylated hydroxyanisole (10 per cent) dissolved in 98 per cent ethanol was added to each sample prior to homogenization. The homogenate was filtered through Whatman No.1 filter paper into 100 ml graduated cylinder and one-fourth volume (on the basis of Folch -1) of 0.88 per cent sodium chloride

solution was added and capped with glass stopper. The filtrate was mixed well. The cylinder was washed twice with 10 ml of Folch – II solution (3: 47: 48 of chloroform: methanol: water) and the contents were separated. The upper layer was siphoned off and the lower layer was taken into a glass scintillation vial and dried at 50<sup>0</sup>C under nitrogen.

Thin layer chromatography was carried out as per the method of Du *et al.* (2000) to check completeness of the transmethylation process. The extracted and dried lipids were dissolved in chloroform to set the final concentration of lipid at 0.2 g per ml. The lipid – chloroform solution (150 µl) was loaded on to an activated (120<sup>0</sup>C for 2 h) silica gel plate (20 x 20 cm). The plate was developed first in solvent – I, composed of chloroform : methanol : water (65 : 25 : 4, vol / vol / vol) until the solvent line reached the middle of the plate. Then the plate was air – dried and redeveloped in solvent – II, composed of hexane: diethyl ether (4: 1 vol / vol) until the solvent front reached one inch below the top of the plate. After air drying for 10 min at room temperature, the plates were sprayed with 0.1 per cent of 2', 7' dichlorofluorescein in ethanol. Lipid classes were identified under UV light and methyl esters were scrapped into separate test tubes and dissolved in hexane and passed on to an anhydrous sodium sulphate column to remove any moisture before injecting into gas chromatography. Fatty acids were identified with reference to the standards and they were quantified as per area normalization method. Then, they were expressed as percentage of total fatty acids. Similar procedure was carried to estimate fatty acid composition of samples of thigh and breast muscles from each treatment.

The fatty acid methyl esters were separated and quantified by gas chromatography using a fused silica capillary column (Supelco 2380) of 30 m x 0.25 mm i.d, 0.25 µ film thickness. Ramped oven temperature conditions (180<sup>0</sup>C for 5 min increased to 220<sup>0</sup>C and held for 5 min) were used. Temperature of both injector and detector were 250 and 260<sup>0</sup>C respectively.

The relative economics of producing n-3 fatty acids enriched chicken meat was calculated on the actual prevailing cost of the feed during the study period. The data was subjected to statistical analysis as per Snedecor and Cochran (1989). Angular transformation is applied to percentages before statistical analysis wherever needed. Data on sensory evaluation of meat was subjected to Kruskal - Wallis K - sample non - parametric test ( Sokal and Rohlf, 1995).

## Results and discussion

The fish oil utilized in this study contained the maximum amount of myristic, palmitic and stearic acid, Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) while linseed and rapeseed oils contained minimum amount. Lands (1986), Sargent and Henderson (1995) and Sargent (1997) reported that the EPA and DHA content of fish oil derived from different varieties of fish ranged from 60 to 170 and 40 to 151 g per kg total fatty acids respectively. Mehta *et al.* (2000<sup>b</sup>) reported that the linolenic acid content of linseed oil ranged from 47.0 to 57.0 per cent which is lower than the value obtained in this study. Erucic acid content of rapeseed oil ranged from 42.0 to 57.7 per cent, which is in agreement with the erucic acid present in rapeseed oil utilized for this experiment (Mehta *et al.* 2000<sup>a</sup>). The total n-3 fatty acids content of linseed oil utilized in the study was higher than that of fish and rapeseed oils, which was highly significant (P<0.01) due to oils. The n-3 / n-6 fatty acids ratio of linseed oil was higher when compared to fish and rapeseed oils and it was found to be highly significant (P<0.01); The results obtained in this study in respect of n-3 / n-6 fatty acids ratio is not agreeable with the reports published by Lands (1986), Sargent and Henderson (1995) and Sargent (1997).

**Table 2.**

**Mean ( $\pm$  S.E.) body weight gain (g), feed consumption (g), feed efficiency, abdominal fat percentage and ready – to- cook yield at 7<sup>th</sup> week of age as influenced by various n-3 lipid sources in feed**

Treatment groups	Body weight gain	Feed consumption	Feed efficiency	Abdominal fat percentage	Net profit per kg ready -to- cook yield <sup>1</sup>
T <sub>1</sub> – Control	1942.19 <sup>bcd</sup> $\pm$ 19.74	4644.33 <sup>c</sup> $\pm$ 37.81	2.39 <sup>b</sup> $\pm$ 0.02	1.90 <sup>c</sup> $\pm$ 0.09	15.24
T <sub>2</sub> – FO 1 %	1958.86 <sup>cde</sup> $\pm$ 08.20	4359.29 <sup>b</sup> $\pm$ 68.30	2.23 <sup>ab</sup> $\pm$ 0.03	1.60 <sup>bc</sup> $\pm$ 0.04	15.79
T <sub>3</sub> – LO 1%	2010.57 <sup>de</sup> $\pm$ 12.37	4288.67 <sup>ab</sup> $\pm$ 80.48	2.13 <sup>a</sup> $\pm$ 0.05	1.60 <sup>bc</sup> $\pm$ 0.80	18.77
T <sub>4</sub> – RO 1%	1800.72 <sup>ab</sup> $\pm$ 35.75	4378.26 <sup>b</sup> $\pm$ 07.90	2.43 <sup>b</sup> $\pm$ 0.05	1.60 <sup>bc</sup> $\pm$ 0.13	13.68
T <sub>5</sub> – FO 2 %	2067.60 <sup>e</sup> $\pm$ 15.60	4382.24 <sup>b</sup> $\pm$ 59.27	2.12 <sup>a</sup> $\pm$ 0.04	1.10 <sup>ab</sup> $\pm$ 0.13	16.82
T <sub>6</sub> – LO 2%	1999.45 <sup>de</sup> $\pm$ 05.47	4257.00 <sup>ab</sup> $\pm$ 41.29	2.13 <sup>a</sup> $\pm$ 0.02	1.10 <sup>ab</sup> $\pm$ 0.11	18.61
T <sub>7</sub> – RO 2%	1885.07 <sup>abcd</sup> $\pm$ 62.53	4370.76 <sup>b</sup> $\pm$ 46.32	2.32 <sup>ab</sup> $\pm$ 0.08	1.20 <sup>abc</sup> $\pm$ 0.19	13.61
T <sub>8</sub> – FO 3 %	1926.74 <sup>abcde</sup> $\pm$ 51.58	4444.29 <sup>bc</sup> $\pm$ 21.79	2.31 <sup>ab</sup> $\pm$ 0.07	0.74 <sup>a</sup> $\pm$ 0.07	14.27
T <sub>9</sub> – LO 3%	1793.07 <sup>a</sup> $\pm$ 87.15	4108.57 <sup>a</sup> $\pm$ 56.62	2.30 <sup>ab</sup> $\pm$ 0.09	0.85 <sup>a</sup> $\pm$ 0.16	14.20
T <sub>10</sub> – RO 3%	1841.93 <sup>abc</sup> $\pm$ 32.17	4383.33 <sup>b</sup> $\pm$ 52.61	2.38 <sup>b</sup> $\pm$ 0.05	0.88 <sup>a</sup> $\pm$ 0.12	12.54
T <sub>11</sub>	1920.17 <sup>abcd</sup> $\pm$ 08.86	4361.26 <sup>b</sup> $\pm$ 74.78	2.27 <sup>ab</sup> $\pm$ 0.04	1.00 <sup>ab</sup> $\pm$ 0.13	17.22
T <sub>12</sub>	1947.95 <sup>cde</sup> $\pm$ 18.15	4346.81 <sup>b</sup> $\pm$ 43.24	2.23 <sup>ab</sup> $\pm$ 0.04	0.89 <sup>a</sup> $\pm$ 0.09	15.65
T <sub>13</sub>	1958.00 <sup>cde</sup> $\pm$ 06.27	4250.14 <sup>ab</sup> $\pm$ 91.81	2.17 <sup>a</sup> $\pm$ 0.04	0.74 <sup>a</sup> $\pm$ 0.06	17.32

a,b,c,... Mean values not sharing a common superscript column wise differ significantly (P< 0.01)

<sup>1</sup>Ready - to - cook yield was worked out by keeping the sale price at Rs.50 per kg.

T<sub>11</sub> – (FO+LO+RO) 1%; T<sub>12</sub> – (FO+LO+RO) 2 %; T<sub>13</sub> – (FO+LO+RO) 3 %;

FO – Fish oil; LO – Linseed oil; RO – Rapeseed oil

From the Table 2, it was evident that supplementation of n-3 lipid sources resulted in highly significant (P<0.01) difference in body weight gain among treatment groups. The body weight of the birds fed diet with three per cent linseed oil had significantly lower body weight gain as compared to control group. In all the other groups, the body weight gain is comparable to that of control group. The above findings are in accordance with the earlier reports of Vogtmann and Clandinin (1974), Phetteplace and Watkins (1990), Chanmugam *et al.* (1992), An *et al.* (1995), Aranibar *et al.* (2001), Coetzee and Hoffman (2001), Crespo and Esteve-Garcia, (2001) and Newman *et al.* (2002). According to Zollitsch *et al.* (1997) there was at least a tendency towards a higher growth rate in the group of broilers which were fed vegetable oils than groups of birds fed animal / vegetable fat blended and a processed fat product. Similarly, Iqbal *et al.* (1998) concluded that the broiler diet containing rapeseed oil was the best for growth compared with tallow or rice bran oil. Moreover, addition of rapeseed oil had a significant growth promoting effect, which are not in agreement with the results obtained in this study.

Inclusion of n-3 lipid sources in broiler diet had significantly ( $P < 0.01$ ) reduced feed consumption from fifth week of age which is in agreement with the earlier reports of Chanmugam *et al.* (1992), An *et al.* (1995), Saricicek *et al.* (1997) and Lopez-Ferrer *et al.* (1999). Crespo and Esteve-Garcia (2001) concluded that feed intake of broilers decreased significantly as dietary linseed oil level increased which is in agreement with the results of this study. Contrary to these results, Lopez – Ferrer *et al.* (1999) observed increased feed consumption in linseed oil fed group. Chanmugam *et al.* (1992), Saricicek *et al.* (1997) and Lopez-Ferrer *et al.* (1999), Zollitsch *et al.* (1997) and Coetzee and Hoffman (2001) observed no significant difference in feed efficiency due to n-3 lipid sources in broiler feed.

Supplementation of various n-3 lipid sources in broiler feed had no deleterious effect on health of the broilers and the livability was uniformly superior in all the treatment groups and found non significant effect on giblets and ready – to – cook yields in this study. The reports of several studies (Saricicek *et al.*, 1997, Crespo and Esteve-Garcia, 2001, Zollitsch *et al.*, 1997 and Osek *et al.*, 2001) also indicated non significant difference due to n-3 lipid source supplementation on ready – to – cook yield of broilers. Abdominal fat pad percentage was significantly ( $P < 0.01$ ) lowered by diets containing two per cent fish oil, linseed oil and three per cent fish, linseed and rapeseed oils and combinations of all the three oils at one, two and three per cent levels. Crespo and Esteve-Garcia, (2002) opined that in general, the analyzed separable fat deposits were reduced in broilers fed linseed oil which is partially agreeable with the results of the study. Lower abdominal fat of birds in the experiment fed poly unsaturated fatty acids suggested that these fatty acids could cause inhibition of lipogenesis, redistribution of lipids in the body or higher energy expenditure despite their higher digestibility in respect to saturated fatty acids (Crespo and Esteve-Garcia, 2001). However, Phetteplace and Watkins (1990), Saricicek *et al.* (1997) and Zollitsch *et al.* (1997) did not find significance on abdominal fat pad weight in broilers fed diet containing fish and rapeseed oils respectively. The study revealed that as the level of n -3 fatty acids sources increased in the broiler diet, the abdominal fat pad weight decreased in broilers.

The statistical analysis failed to show significant effect due to dietary treatments on breast and thigh meat on appearance, juiciness, flavour, tenderness and overall acceptability scores of broilers. Egorov and Chesnokova (1990) reported that broilers fed on the basal diet without or with rapeseed oil added at two, three or four per cent had no differences in organoleptic value of the meat which is in agreement with the results of this study. Lopez-Ferrer *et al.* (1999) reported that the meat samples (breast and thigh muscles) of broilers fed diets with 8.2 per cent fish oil from zero to five weeks had the poorest sensory quality scores. Moreover, the use of fish oil in the diets at the level studied up to the period of slaughter clearly caused deterioration in the sensory quality of the cooked meat rendering their use unsuitable. Contrary to the report, incorporation of fish oil up to three per cent level did not show deterioration in sensory quality of cooked meat and taste panelist accepted the quality in this study.

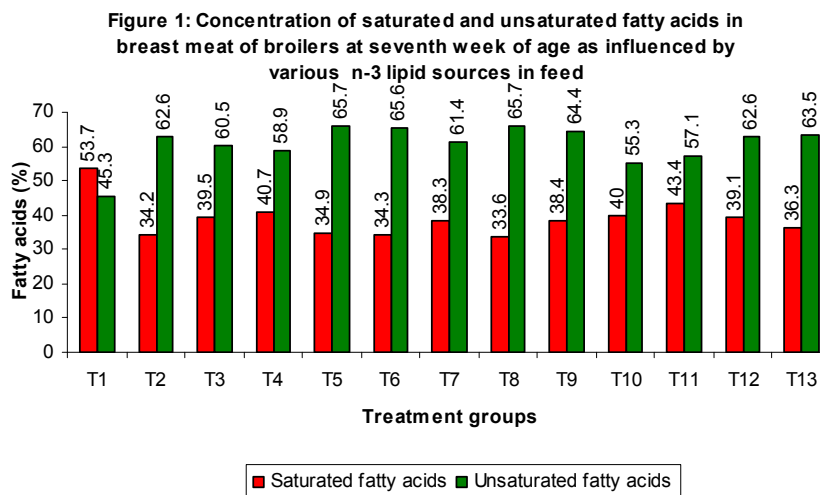


Table 3

Mean ( $\pm$  S.E.) fatty acids composition (%) of breast muscle of broilers at seventh week of age as influenced by various n-3 lipid sources in feed

Treatment Groups	Myristic acid	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	EPA	DHA	Total n-3 fatty acids	Total n-6 fatty acids	Total n-3 / n-6 fatty acids ratio
T <sub>1</sub> – Control	2.00 <sup>d</sup> ± 0.35	32.70 <sup>e</sup> ± 0.64	19.50 <sup>c</sup> ± 0.60	30.10 <sup>ab</sup> ± 0.20	13.00 <sup>a</sup> ± 0.36	0.76 <sup>a</sup> ± 0.22	0.60 <sup>a</sup> ± 0.20	0.65 <sup>a</sup> ± 0.35	2.00 <sup>a</sup> ± 0.20	13.30 <sup>ab</sup> ± 0.36	0.15 <sup>a</sup> ± 0.25
T <sub>2</sub> – FO 1%	1.00 <sup>bc</sup> ± 0.49	22.10 <sup>ab</sup> ± 0.44	13.50 <sup>ab</sup> ± 0.54	34.30 <sup>bcd</sup> ± 0.72	14.60 <sup>abc</sup> ± 0.37	2.60 <sup>b</sup> ± 0.64	3.10 <sup>d</sup> ± 0.46	7.10 <sup>d</sup> ± 0.65	13.10 <sup>e</sup> ± 0.45	14.50 <sup>abc</sup> ± 0.37	0.94 <sup>cd</sup> ± 0.26
T <sub>3</sub> – LO 1%	1.10 <sup>bc</sup> ± 0.29	23.10 <sup>ab</sup> ± 0.25	14.90 <sup>b</sup> ± 0.54	35.50 <sup>cd</sup> ± 0.30	18.40 <sup>def</sup> ± 0.60	4.70 <sup>c</sup> ± 0.40	0.53 <sup>a</sup> ± 0.57	1.10 <sup>ab</sup> ± 0.45	6.40 <sup>b</sup> ± 0.31	18.40 <sup>def</sup> ± 0.60	0.59 <sup>bc</sup> ± 0.90
T <sub>4</sub> – RO 1%	0.95 <sup>bc</sup> ± 0.23	26.10 <sup>bcd</sup> ± 0.96	14.70 <sup>b</sup> ± 0.74	35.70 <sup>cd</sup> ± 0.41	16.30 <sup>bcd</sup> ± 0.81	4.70 <sup>c</sup> ± 0.43	0.63 <sup>a</sup> ± 0.25	1.10 <sup>ab</sup> ± 0.24	6.50 <sup>b</sup> ± 0.35	16.30 <sup>bcd</sup> ± 0.81	0.40 <sup>b</sup> ± 0.15
T <sub>5</sub> – FO 2%	1.00 <sup>bc</sup> ± 0.10	21.20 <sup>ab</sup> ± 0.15	11.90 <sup>ab</sup> ± 0.43	31.60 <sup>abcd</sup> ± 0.45	15.10 <sup>abcd</sup> ± 0.17	3.20 <sup>b</sup> ± 0.50	5.60 <sup>e</sup> ± 0.22	9.90 <sup>e</sup> ± 0.39	18.80 <sup>g</sup> ± 0.42	15.10 <sup>abcd</sup> ± 0.16	1.20 <sup>d</sup> ± 0.11
T <sub>6</sub> – LO 2%	0.96 <sup>bc</sup> ± 0.15	21.11 <sup>a</sup> ± 0.35	12.10 <sup>ab</sup> ± 0.98	36.30 <sup>d</sup> ± 0.90	21.30 <sup>f</sup> ± 0.72	5.90 <sup>cd</sup> ± 0.37	0.71 <sup>a</sup> ± 0.14	1.30 <sup>b</sup> ± 0.22	7.90 <sup>bc</sup> ± 0.36	21.30 <sup>f</sup> ± 0.72	0.37 <sup>b</sup> ± 0.14
T <sub>7</sub> – RO 2%	0.87 <sup>ab</sup> ± 0.42	23.30 <sup>abc</sup> ± 0.96	13.30 <sup>ab</sup> ± 0.85	35.30 <sup>cd</sup> ± 0.57	19.10 <sup>ef</sup> ± 0.99	4.80 <sup>c</sup> ± 0.57	0.70 <sup>a</sup> ± 0.10	1.20 <sup>b</sup> ± 0.17	6.80 <sup>b</sup> ± 0.49	19.10 <sup>ef</sup> ± 0.99	0.36 <sup>b</sup> ± 0.13
T <sub>8</sub> – FO 3%	0.70 <sup>ab</sup> ± 0.44	23.20 <sup>abc</sup> ± 1.20	10.70 <sup>a</sup> ± 1.16	29.40 <sup>a</sup> ± 1.41	14.50 <sup>ab</sup> ± 0.93	2.70 <sup>b</sup> ± 0.41	7.50 <sup>f</sup> ± 0.40	12.60 <sup>f</sup> ± 0.29	22.90 <sup>h</sup> ± 0.45	13.00 <sup>a</sup> ± 0.93	1.80 <sup>e</sup> ± 0.29
T <sub>9</sub> – LO 3%	1.20 <sup>bc</sup> ± 0.34	22.00 <sup>ab</sup> ± 1.83	10.80 <sup>a</sup> ± 0.79	34.20 <sup>bcd</sup> ± 0.57	19.30 <sup>ef</sup> ± 0.87	7.70 <sup>d</sup> ± 2.00	1.30 <sup>bc</sup> ± 0.16	1.30 <sup>b</sup> ± 0.22	10.20 <sup>d</sup> ± 1.40	19.30 <sup>ef</sup> ± 0.87	0.53 <sup>b</sup> ± 0.32
T <sub>10</sub> – RO 3%	0.98 <sup>bc</sup> ± 0.41	29.60 <sup>de</sup> ± 0.85	13.80 <sup>ab</sup> ± 0.86	29.80 <sup>ab</sup> ± 1.24	16.80 <sup>cde</sup> ± 0.94	5.90 <sup>cd</sup> ± 0.83	1.40 <sup>c</sup> ± 0.23	1.40 <sup>b</sup> ± 0.17	8.90 <sup>cd</sup> ± 0.69	16.80 <sup>cde</sup> ± 0.94	0.51 <sup>b</sup> ± 0.25
T <sub>11</sub>	1.00 <sup>bc</sup> ± 0.58	28.30 <sup>cde</sup> ± 0.57	13.30 <sup>ab</sup> ± 0.47	31.00 <sup>abc</sup> ± 0.86	16.60 <sup>cde</sup> ± 0.26	2.70 <sup>b</sup> ± 0.46	1.10 <sup>b</sup> ± 0.17	5.40 <sup>c</sup> ± 0.55	9.40 <sup>cd</sup> ± 0.44	16.60 <sup>cde</sup> ± 0.26	0.56 <sup>b</sup> ± 0.12
T <sub>12</sub>	0.84 <sup>ab</sup> ± 0.44	25.60 <sup>abcd</sup> ± 0.67	12.40 <sup>ab</sup> ± 0.68	29.10 <sup>a</sup> ± 0.49	16.00 <sup>abcde</sup> ± 0.75	4.90 <sup>c</sup> ± 0.42	1.00 <sup>b</sup> ± 0.16	9.40 <sup>e</sup> ± 0.91	15.60 <sup>ef</sup> ± 0.71	16.00 <sup>abcde</sup> ± 0.75	0.95 <sup>d</sup> ± 0.27
T <sub>13</sub>	0.55 <sup>a</sup> ± 0.42	24.60 <sup>abcd</sup> ± 1.19	11.00 <sup>a</sup> ± 0.54	29.70 <sup>ab</sup> ± 0.70	17.10 <sup>cdef</sup> ± 0.59	4.90 <sup>c</sup> ± 0.25	1.60 <sup>c</sup> ± 0.19	9.80 <sup>e</sup> ± 0.60	16.50 <sup>fg</sup> ± 0.56	17.10 <sup>cde</sup> ± 0.59	0.96 <sup>d</sup> ± 0.13

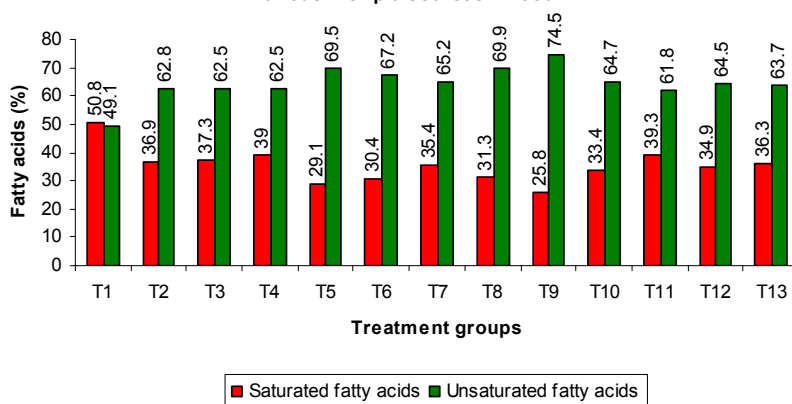
a,b,c,... Mean values not sharing a common superscript column wise differ significantly (P< 0.01)

T<sub>11</sub> – (FO+LO+RO) 1%; T<sub>12</sub> – (FO+LO+RO) 2 %; T<sub>13</sub> – (FO+LO+RO) 3 %

FO – Fish oil; LO – Linseed oil; RO -Rapeseed oil

The mean percentage of myristic acid, palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, Eicosapentaenoic acid (EPA), Docosahexaenoic acid (DHA), total n-3 fatty acids, total n-6 fatty acids and total n-3 / n-6 fatty acids ratio in broiler breast and thigh meat estimated by Gas chromatography are given in Table 3 and 4 respectively. From the tables, it was observed that there was significant decrease in values of myristic, palmitic and stearic acids in all treated groups. However in control group, the breast meat showed the higher values of the above acids when compared to thigh meat. Oleic, linoleic, linolenic acids, EPA, DHA, total n-3 fatty acids, total n-6 fatty acids and total n-3 / n-6 fatty acids ratio increased in breast and thigh meat of broilers fed n-3 lipid sources were highly significant (P<0.01).

**Figure 2: Concentration of saturated and unsaturated fatty acids in Thigh meat of broilers at seventh week of age as influenced by various n-3 lipid sources in feed**



**Table 4.**

**Mean ( $\pm$  S.E.) fatty acids composition (%) of thigh muscle of broilers at seventh week of age as influenced by various n-3 lipid sources in feed**

Treatment Groups	Myristic acid	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	EPA	DHA	Total n-3 fatty acids	Total n-6 fatty acids	Total n-3 / n-6 fatty acids ratio
T <sub>1</sub> – Control	1.70 <sup>g</sup> ±0.25	29.50 <sup>f</sup> ±0.85	17.80 <sup>h</sup> ±0.57	34.40 <sup>a</sup> ±0.45	13.10 <sup>ab</sup> ±0.16	0.65 <sup>a</sup> ±0.44	0.26 <sup>ab</sup> ±0.24	0.53 <sup>a</sup> ±0.27	1.40 <sup>a</sup> ±0.53	13.10 <sup>ab</sup> ±0.16	0.10 <sup>a</sup> ±0.15
T <sub>2</sub> – FO 1%	0.60 <sup>de</sup> ±0.33	23.50 <sup>de</sup> ±0.87	12.70 <sup>defg</sup> ±0.52	40.40 <sup>cde</sup> ±0.85	13.90 <sup>abc</sup> ±1.09	2.00 <sup>b</sup> ±0.27	3.70 <sup>d</sup> ±0.20	2.70 <sup>d</sup> ±0.37	8.50 <sup>de</sup> ±0.21	13.80 <sup>abc</sup> ±1.19	0.63 <sup>d</sup> ±0.26
T <sub>3</sub> – LO 1%	0.78 <sup>ef</sup> ±0.15	23.60 <sup>de</sup> ±0.97	12.90 <sup>eig</sup> ±0.17	41.20 <sup>def</sup> ±1.58	15.50 <sup>bcd</sup> ±1.13	3.70 <sup>de</sup> ±0.28	0.23 <sup>a</sup> ±0.77	0.91 <sup>ab</sup> ±0.41	5.60 <sup>bc</sup> ±0.25	15.60 <sup>bcd</sup> ±1.13	0.36 <sup>b</sup> ±0.17
T <sub>4</sub> – RO 1%	0.86 <sup>ef</sup> ±0.17	24.40 <sup>de</sup> ±0.71	13.90 <sup>ig</sup> ±0.79	40.70 <sup>de</sup> ±0.40	15.10 <sup>bcd</sup> ±1.11	2.20 <sup>bc</sup> ±0.72	0.40 <sup>ab</sup> ±0.85	1.50 <sup>bc</sup> ±0.73	4.80 <sup>b</sup> ±0.80	15.10 <sup>bcd</sup> ±1.11	0.32 <sup>b</sup> ±0.31
T <sub>5</sub> – FO 2%	0.86 <sup>ef</sup> ±0.20	14.80 <sup>b</sup> ±0.60	09.50 <sup>ab</sup> ±0.38	40.40 <sup>cde</sup> ±0.65	14.40 <sup>abcd</sup> ±0.74	4.20 <sup>ef</sup> ±0.18	0.60 <sup>e</sup> ±0.26	5.50 <sup>ig</sup> ±0.57	15.80 <sup>f</sup> ±0.48	14.40 <sup>abcd</sup> ±0.74	1.00 <sup>e</sup> ±0.23
T <sub>6</sub> – LO 2%	0.63 <sup>de</sup> ±0.20	19.40 <sup>bc</sup> ±0.30	10.40 <sup>bc</sup> ±0.19	42.30 <sup>ef</sup> ±0.19	17.00 <sup>de</sup> ±0.40	6.14 <sup>g</sup> ±0.17	1.70 <sup>c</sup> ±1.67	1.00 <sup>ab</sup> ±0.16	9.40 <sup>de</sup> ±0.71	17.00 <sup>de</sup> ±0.40	0.58 <sup>cd</sup> ±0.17
T <sub>7</sub> – RO 2%	0.96 <sup>f</sup> ±0.02	22.40 <sup>cde</sup> ±0.49	11.90 <sup>cde</sup> ±0.44	41.40 <sup>def</sup> ±0.36	14.20 <sup>abcd</sup> ±0.57	4.80 <sup>ef</sup> ±0.12	1.40 <sup>c</sup> ±1.92	2.70 <sup>d</sup> ±0.91	8.80 <sup>de</sup> ±0.35	13.60 <sup>ab</sup> ±0.34	0.62 <sup>d</sup> ±0.17
T <sub>8</sub> – FO 3%	0.30 <sup>ab</sup> ±0.19	19.70 <sup>bc</sup> ±0.74	11.20 <sup>cd</sup> ±0.33	38.50 <sup>bcd</sup> ±1.08	11.90 <sup>a</sup> ±0.32	3.00 <sup>cd</sup> ±0.38	9.10 <sup>f</sup> ±0.27	5.90 <sup>g</sup> ±0.70	18.10 <sup>f</sup> ±0.49	12.10 <sup>a</sup> ±0.38	1.50 <sup>f</sup> ±0.23
T <sub>9</sub> – LO 3%	0.24 <sup>a</sup> ±0.17	14.60 <sup>a</sup> ±0.45	08.50 <sup>a</sup> ±0.24	44.70 <sup>f</sup> ±0.28	22.40 <sup>f</sup> 0.35	7.85 <sup>h</sup> ±0.68	1.50 <sup>c</sup> ±0.32	1.60 <sup>bc</sup> ±0.38	9.30 <sup>de</sup> ±0.54	22.70 <sup>f</sup> ±0.35	0.41 <sup>bc</sup> ±0.13
T <sub>10</sub> – RO 3%	0.50 <sup>bcd</sup> ±0.30	19.50 <sup>bcd</sup> ±0.43	12.00 <sup>cde</sup> ±0.40	39.60 <sup>bcd</sup> ±0.38	17.40 <sup>de</sup> ±0.26	5.10 <sup>ig</sup> ±0.46	1.70 <sup>c</sup> ±0.09	2.50 <sup>cd</sup> ±0.50	9.00 <sup>de</sup> ±0.18	17.70 <sup>de</sup> ±0.27	0.45 <sup>bcd</sup> ±0.40
T <sub>11</sub>	0.51 <sup>cd</sup> ±0.24	24.60 <sup>e</sup> ±0.41	14.20 <sup>g</sup> ±0.12	34.50 <sup>ab</sup> ±0.10	17.10 <sup>de</sup> ±0.26	2.10 <sup>bc</sup> ±0.10	1.30 <sup>c</sup> ±0.27	3.60 <sup>de</sup> ±0.11	7.20 <sup>cd</sup> ±0.18	16.90 <sup>de</sup> ±0.28	0.42 <sup>bc</sup> ±0.13
T <sub>12</sub>	0.41 <sup>abcd</sup> ±0.35	22.10 <sup>cde</sup> ±0.47	12.30 <sup>defg</sup> ±0.33	37.50 <sup>abcd</sup> ±0.42	19.80 <sup>ef</sup> ±0.56	2.30 <sup>bc</sup> ±0.35	1.00 <sup>bc</sup> ±0.13	3.70 <sup>ef</sup> ±0.52	7.50 <sup>d</sup> ±0.51	19.70 <sup>ef</sup> ±0.54	0.38 <sup>b</sup> ±0.13
T <sub>13</sub>	0.36 <sup>abc</sup> ±0.39	23.60 <sup>de</sup> ±0.50	12.70 <sup>defg</sup> ±0.49	36.70 <sup>abc</sup> ±0.17	16.80 <sup>cde</sup> ±0.39	3.90 <sup>de</sup> ±0.69	1.50 <sup>c</sup> ±0.23	4.40 <sup>efg</sup> ±0.56	10.00 <sup>e</sup> ±0.73	16.90 <sup>cde</sup> ±0.35	0.59 <sup>cd</sup> ±0.21

a,b,c,... Mean values not sharing a common superscript column wise differ significantly (P< 0.01)

T<sub>11</sub> – (FO+LO+RO) 1%; T<sub>12</sub> – (FO+LO+RO) 2 %; T<sub>13</sub> – (FO+LO+RO) 3 %

FO – Fish oil; LO – Linseed oil; RO -Rapeseed oil

Similar to these results, Miller and Robisch (1969) reported that the fish oils at 1.5 and 2.5 per cent level fed to broilers had influenced the fatty acid patterns of the tissue lipids. Crespo and Esteve - Garcia (2001) observed that birds fed with linseed oil presented the highest values of linolenic acid in all tissues, which is in agreement with the results of this study. Chanmugam *et al.* (1992) found that levels of EPA were increased ( $P < 0.05$ ) in all the groups fed with fish oil than other groups which is in agreement with the results of this study. He further observed that birds supplemented with diet rich in linolenic acid content had significantly higher levels of n-3 fatty acids and high n-3 : n-6 ratio than those supplemented with same level of fish oil which is not in agreement with the results of this study. However, they concluded that to increase the n-3 : n-6 ratio in meat, oils with a high content of linolenic acid could be used in poultry feeds. In general, the total unsaturated fatty acids concentration in breast (Fig.1) and thigh meat (Fig.2) of broilers showed an increase in all the treated groups due to incorporation of various n-3 lipid sources in feed.

The net profit per kg live weight and net profit per ready – to – cook yield in broiler groups fed rapeseed oil at one, two and three per cent levels were found to be lowest than other treatment groups, which is possibly be due to the relatively higher cost of rapeseed oil. However Iqbal *et al.* (1998) observed a higher net profit per bird with diets containing rapeseed oil which was comparatively costlier. From this study, it was observed that supplementation of linseed oil at one per cent level to broilers increased the profit margin as net profit per bird and net profit per kg ready-to-cook meat when compared to unsupplemented group, which is possibly be due to better body weight, better feed efficiency and relatively better ready – to – cook yield.

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