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Production of chicken designer meat by manipulating fatty acids composition with Omega-3- fatty acids feed ingredients

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ABSTRACT

A 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. The supplementation of n-3 lipid sources in broiler ration had significant increase in Omega – 3 fatty acids composition such as linolenic acid (LNA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), total n-3, total n-3/n-6 fatty acids ratio of broiler meat and a significant reduction in palmitic and stearic acid concentrations. The inclusion of n-3 lipid sources in broiler ration had no adverse effect on meat quality in terms of organoleptic assessment such as appearance, juiciness, flavour, tenderness and overall acceptability scores.

Key words: Chicken designer meat, Omega -3- fatty acids

Foods enriched with n-3 fatty acids are gaining popularity and are 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 (Galli *et al*. 1994) particularly in diabetics and also provide essential nutrients required for brain and visual development in children and enhance immunity in adults. Fish, linseed and algae are rich sources of omega -3 fatty acids and may be utilized to engineer commonly consumed foods with beneficial components especially n-3 fatty acids. Poultry has a peculiar capability of incorporating not only these omega -3 fatty acids but also anti-oxidants and immuno-modulators. Hence, an attempt was made to engineer designer chicken meat by manipulating the fatty acids composition of meat by altering their dietary rations.

Table 1. Treatment groups and experimental diet of broilers

Treatment groups	Experimental diet	Treatment groups	Experimental diet
T_1	Basal feed (control)		
T_2	Basal feed + Fish oil 1%	T_8	Basal feed + Fish oil 3%
T_3	Basal feed + Linseed oil 1%	T_9	Basal feed + Linseed oil 3%
T_4	Basal feed + Rapeseed oil 1%	T_{10}	Basal feed + Rapeseed oil 3%
T_5	Basal feed + Fish oil 2%	T_{11}	Basal feed + (Fish oil +Linseed oil +Rapeseed oil) 1%
T_6	Basal feed + Linseed oil 2%	T_{12}	Basal feed + (Fish oil +Linseed oil +Rapeseed oil) 2%
T_7	Basal feed + Rapeseed oil 2%	T_{13}	Basal feed +(Fish oil + Linseed oil+ Rapeseed oil) 3%

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MATERIALS AND METHODS

Two hundred and seventy three day old broiler chicks were obtained from a local commercial hatchery and were weighed, wing banded and randomly allotted to thirteen treatment groups with three replicates having seven broiler chicks each. Experimental diets were prepared by incorporating graded levels either independently or simultaneously of known quantities of fish, linseed and rapeseed oils as n-3 lipid sources to broiler basal diets (Table 1). The per cent composition of the experimental

Table 2. Composition of broiler- starter mash

Name of the feed ingredient	T_1 Control	T_2 1% FO*	T_3 1% LO*	T_4 1% RO*	T_5 2% FO	T_6 2% LO	T_7 2% RO	T_8 3% FO	T_9 3% LO	T_{10} 3% RO	T_{11} (0.33%FO+ 0.33%LO+ 0.33%RO)	T_{12} (0.66%FO+ 0.66%LO+ 0.66%RO)	T_{13} (0.99%FO+ 0.99%LO+ 0.99%RO)
Maize	50.50	46.00	44.80	44.80	40.70	40.00	40.00	36.40	35.00	35.00	46.00	40.50	35.50
D.O.R.B.	07.10	10.70	12.75	12.75	16.00	16.00	16.00	18.80	20.30	20.30	10.51	15.72	19.83
Soya	39.00	38.80	38.20	38.20	38.00	38.30	38.30	38.10	38.00	38.00	38.80	38.10	38.00
Mineral mixture	03.40	02.50	02.50	02.50	03.30	03.70	03.70	03.70	03.70	03.70	03.70	03.70	03.70
Fish oil	0	01.00	0	0	02.00	0	0	03.00	0	0	00.33	00.66	00.99
Linseed oil	0	0	01.00	0	0	02.00	0	0	03.00	0	00.33	00.66	00.99
Rapeseed oil	0	0	0	01.0	0	0	02.00	0	0	03.00	00.33	00.66	00.99
Total	100	100	100	100	100	100	100	100	100	100	100	100	100
Supplements (g)													
Vitamin AB_2D_3K [1]	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
B-complex vitamins [2]	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Trace minerals [3]	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00

* FO, fish oil; LO, linseed oil and RO, Rapeseed oil[1], 1g vitamin AB_2D_3K supplement contained: 82500 IU of vitamin-A, 50 mg of vitamin-B_2 , 12000 IU of vitamin-D_3 and 10 mg of vitamin-K; [2] , 1g B-complex supplement contained: 8 mg of vitamin B_1, 16 mg of vitamin B_6, 80 mg of vitamin B_{12}, 80 mg of vitamin E, 120 mg of niacin, 8 mg of folic acid, 80 mg of calcium pantothenate, 120 mg of calcium and 300 mg of phosphate. [3] , 1g trace minerals contained: 54 mg of manganese, 52 mg of zinc, 20 mg of iron, 2 mg of iodine and 1 mg of cobalt.

Table 3. Composition of broiler-finisher mash

Name of the feed ingredient	T_1 Control	T_2 1% FO*	T_3 1% LO*	T_4 1% RO*	T_5 2% FO	T_6 2% LO	T_7 2% RO	T_8 3% FO	T_9 3% LO	T_{10} 3% RO	T_{11} (0.33%FO+ 0.33%LO+ 0.33%RO)	T_{12} (0.66%FO+ 0.66%LO+ 0.66%RO)	T_{13} (0.99%FO+ 0.99%LO+ 0.99%RO)
Maize	62.00	57.20	56.20	56.202	51.90	50.80	50.60	47.00	45.50	45.50	56.41	51.50	46.00
D.O.R.B.	03.50	07.50	08.80	08.80	12.40	13.80	14.00	16.60	18.50	18.50	8.70	12.72	17.53
Soya	31.00	30.80	30.50	30.50	30.30	30.00	30.00	30.00	29.60	29.60	30.50	30.30	30.00
Mineral mixture	03.50	03.50	03.50	03.50	03.40	03.40	03.40	03.40	03.40	03.40	03.40	03.50	03.50
Fish oil	0	01.00	0	0	02.00	0	0	03.00	0	0	00.33	00.66	00.99
Linseed oil	0	0	01.0	0	0	02.00	0	0	03.00	0	00.33	00.66	00.99
Rapeseed oil	0	0	0	01.00	0	0	02.00	0	0	03.00	00.33	00.66	00.99
Total	100	100	100	100	100	100	100	100	100	100	100	100	100
Supplements (g)													
Vitamin AB_2D_3K [1]	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
B-complex vitamins [2]	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Trace minerals [3]	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00

* FO, fish oil; LO, linseed oil; RO, rapeseed oil. [1] , 1g vitamin AB_2D_3K supplement contained: 82500 IU of vitamin A, 50 mg of vitamin B_2 , 12000 IU of vitamin D_3 and 10 mg of vitamin K. [2] , 1g B-complex supplement contained: 8 mg of vitamin B_1, 16 mg of vitamin B_6, 80 mg of vitamin B_{12}, 80 mg of vitamin E, 120 mg of niacin, 8 mg of folic acid, 80 mg of calcium pantothenate, 120 mg of calcium and 300 mg of phosphate. [3] , 1g trace minerals contained: 54 mg of manganese, 52 mg of zinc, 20 mg of iron, 2 mg of iodine and 1 mg of cobalt.

diets are provided in Table 2 and 3. The birds were fed with experimental diets *ad lib*. up to 7 weeks of age.

At the end of the seventh week eight birds (4 males and 4 females) were sacrificed (Arumugam and Panda 1970). Breast and thigh meat samples were collected from each bird and stored at –20º C for the estimation of fatty acid composition.

The organoleptic assessment involved cooking of uniform sized samples of fresh breast and thigh muscles at 15 psi for 15 min. The cooked muscles of breast and thigh were served hot separately to an eight-member semi trained taste panel. The results were 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).

The lipids were extracted as per the standard procedure of Folch *et al*. (1957) and transmethylation procedure was carried out as per the method of Sukhija and Palmquist (1988). The fatty acid methyl esters were separated and quantified by gas chromatography using a fused silica capillary column of 30 m × 0.25 mm i.d, 0.25 µ film thickness. Ramped oven temperature conditions (180ºC for 5 min increased to 220º C and held for 5 min) were used. Temperature of both injector and detector were 250º and 260ºC respectively. The data was subjected to statistical analysis as per Snedecor and Cochran (1989). Angular transformation was applied to percentages before statistical analysis.

RESULTS AND DISCUSSION

Data pertaining to various fatty acid values and organoleptic evaluation of the breast and thigh meat of the birds offered various diets is presented in Table 4, 5 and 6. There was a significant (P<0.01) decrease in total saturated fatty acids in thigh and breast muscles in all the treatment groups. Similar results were reported by Said *et al*. (2008), removing poultry fat (PF) from diet by replacement of fish oil (FO) [3% PF, 2% PF +1% FO, 1% PF +2% FO and 3% FO] in broiler ration significantly (P<0. 01) decreased palmitic and stearic acids. The statistical analysis showed that the increase in LNA, EPA, DHA in breast and thigh meat of broilers fed n-3 lipid sources was highly significant (P<0.01). Supplementation of fish oil at graded levels (1, 2 and 3%) increased the total n-3 fatty acids in breast and

Table 4. Mean (± SE) fatty acids composition (%) in breast muscle of broilers at seventh week of age as influenced by various n-3 lipid sources in feed

Treatment groups	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	EPA	DHA	Total n-3	Total n-6	n-3 / n- 6 ratio
T_1 – Control	32.70 e ± 0.64	19.50^{c} ± 0.60	30.10^{ab} ± 0.20	13.00^{a} ± 0.36	00.76a ± 0.22	00.60^{a} ± 0.20	00.65^{a} ± 0.35	02.00^{a} ± 0.20	13.30^{ab} ± 0.36	00.15a ± 0.25
T_2 – FO 1%	22.10^{ab} ± 0.44	13.50^{ab} ± 0.54	34.30 ^{bcd} ± 0.72	14.60^{abc} ± 0.37	02.60 ^{b} ± 0.64	03.10^{d} ± 0.46	07.10^{d} ± 0.65	13.10^{e} ± 0.45	14.50^{abc} ± 0.37	00.94^{cd} ± 0.26
T_3 – LO 1%	23.10^{ab} ± 0.25	14.90 ^{b} ± 0.54	35.50^{cd} ± 0.30	18.40^{def} ± 0.60	04.70^{c} ± 0.40	00.53^{a} ± 0.57	01.10^{ab} ± 0.45	06.40^{b} ± 0.31	18.40^{def} ± 0.60	00.59 ^{bc} ± 0.90
T_4 – RO 1%	26.10 ^{bcd} ± 0.96	14.70 ^{b} ± 0.74	35.70^{cd} ± 0.41	16.30 ^{bcde} ± 0.81	04.70^{c} ± 0.43	00.63^{a} ± 0.25	01.10^{ab} ± 0.24	06.50^{b} ± 0.35	16.30 ^{bcde} ± 0.81	00.40^{b} ± 0.15
T_5 – FO 2 %	21.20^{ab} ± 0.15	11.90^{ab} ± 0.43	31.60^{abcd} ± 0.45	15.10^{abcd} ± 0.17	03.20 ^{b} ± 0.50	05.60 ^{e} ± 0.22	09.90^{e} ± 0.39	18.80 g ± 0.42	15.10^{abcd} ± 0.16	01.20^{d} ± 0.11
T_6 – LO 2%	21.11^{a} ± 0.35	12.10^{ab} ± 0.98	36.30^{d} ± 0.90	21.30 ^{f} ± 0.72	05.90^{cd} ± 0.37	00.71^{a} ± 0.14	01.30^{b} ± 0.22	07.90^{bc} ± 0.36	21.30 ^{f} ± 0.72	00.37^{b} ± 0.14
T_7 – RO 2%	23.30^{abc} ± 0.96	13.30^{ab} ± 0.85	35.30^{cd} ± 0.57	19.10 ^{ef} ± 0.99	04.80^{c} ± 0.57	00.70^{a} ± 0.10	01.20^{b} ± 0.17	06.80^{b} ± 0.49	19.10 ^{ef} ± 0.99	00.36^{b} ± 0.13
T_8 – FO 3 %	23.20^{abc} ± 1.20	10.70^{a} ± 1.16	29.40^{a} ± 1.41	14.50^{ab} ± 0.93	02.70 ^{b} ± 0.41	07.50 ^{f} ± 0.40	12.60^{f} ± 0.29	22.90 h ± 0.45	13.00^{a} ± 0.93	01.80^{e} ± 0.29
T_9 – LO 3%	22.00^{ab} ± 1.83	10.80^{a} ± 0.79	34.20 ^{bcd} ± 0.57	19.30 ^{ef} ± 0.87	07.70^{d} ± 2.00	01.30 ^{bc} ± 0.16	01.30^{b} ± 0.22	10.20^{d} ± 1.40	19.30 ^{ef} ± 0.87	00.53^{b} ± 0.32
T_{10} – RO 3%	29.60^{de} ± 0.85	13.80^{ab} ± 0.86	29.80^{ab} ± 1.24	16.80^{cde} ± 0.94	05.90^{cd} ± 0.83	01.40^{c} ± 0.23	01.40 ^{b} ± 0.17	08.90^{cd} ± 0.69	16.80^{cde} ± 0.94	00.51 ^{b} ± 0.25
T_{11} – (FO + LO + RO) 1%	28.30^{cde} ± 0.57	13.30^{ab} ± 0.47	31.00^{abc} ± 0.86	16.60^{cde} ± 0.26	02.70 ^{b} ± 0.46	01.10 ^{b} ± 0.17	05.40^{c} ± 0.55	09.40^{cd} ± 0.44	16.60^{cde} ± 0.26	00.56^{b} ± 0.12
T_{12} – (FO + LO + RO) 2%	25.60^{abcd} ± 0.67	12.40^{ab} ± 0.68	29.10^{a} ± 0.49	16.00^{abcde} ± 0.75	04.90^{c} ± 0.42	01.00^{b} ± 0.16	09.40^{e} ± 0.91	15.60^{ef} ± 0.71	16.00^{abcde} ± 0.75	00.95^{d} ± 0.27
T_{13} – (FO + LO + RO) 3%	24.60^{abcd} ± 1.19	11.00^{a} ± 0.54	29.70^{ab} ± 0.70	17.10^{cdef} ± 0.59	04.90^{c} ± 0.25	01.60^{c} ± 0.19	09.80^{e} ± 0.60	16.50^{fg} ± 0.56	17.10^{cde} ± 0.59	00.96^{d} ± 0.13

FO, fish oil; LO, linseed oil; RO, rapeseed oil. Mean values not sharing a common superscript columnwise differ significantly (P< 0.01).

Table 5. Mean (± SE) fatty acids composition (%) in thigh muscle of broilers at seventh week of age as influenced by various n - 3 lipid sources in feed

Treatment groups	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	EPA	DHA	Total n-3	Total n-6	n-3 / n- 6 ratio
T_1 – Control	29.50^{f}	17.80^{h}	34.40^{a}	13.10^{ab}	00.65^{a}	00.26^{ab}	00.53a	01.40a	13.10a^{b}	00.10^{a}
	±0.85	±0.57	±0.45	±0.16	±0.44	±0.24	±0.27	±0.53	±0.16	±0.15
T_2 – FO 1%	23.50^{de}	12.70 ^{defg}	40.40 ^{cde}	13.90^{abc}	02.00 ^{b}	03.70 ^{d}	02.70 ^{d}	08.50 ^{de}	13.80^{abc}	00.63 ^{d}
	±0.87	±0.52	±0.85	±1.09	±0.27	±0.20	±0.37	±0.21	±1.19	±0.26
T_3 – LO 1%	23.60 ^{de}	12.90 ^{efg}	41.20 ^{def}	15.50 ^{bcd}	03.70 ^{de}	00.23^{a}	00.91^{ab}	05.60 ^{bc}	15.60 ^{bcd}	00.36 ^{b}
	±0.97	±0.17	±1.58	±1.13	±0.28	±0.77	±0.41	±0.25	±1.13	±0.17
T_4 –RO 1%	24.40 ^{de}	13.90 ^{fg}	40.70 ^{de}	15.10 ^{bcd}	02.20 ^{bc}	00.40^{ab}	01.50 ^{bc}	04.80 ^{b}	15.10 ^{bcd}	00.32 ^{b}
	±0.71	±0.79	±0.40	±1.11	±0.72	±0.85	±0.73	±0.80	±1.11	±0.31
T_5 – FO 2 %	14.80 ^{b}	09.50^{ab}	40.40 ^{cde}	14.40^{abcd}	04.20 ^{ef}	00.60 ^{e}	05.50 ^{fg}	15.80 ^{f}	14.40^{abcd}	01.00 ^{e}
	±0.60	±0.38	±0.65	±0.74	±0.18	±0.26	±0.57	±0.48	±0.74	±0.23
T_6 – LO 2%	19.40 ^{bc}	10.40 ^{bc}	42.30 ^{ef}	17.00 ^{de}	06.14 ^{g}	01.70 ^{c}	01.00^{ab}	09.40 ^{de}	17.00 ^{de}	00.58 ^{cd}
	±0.30	±0.19	±0.19	±0.40	±0.17	±1.67	±0.16	±0.71	±0.40	±0.17
T_7 – RO 2%	22.40 ^{cde}	11.90 ^{cde}	41.40 ^{def}	14.20^{abcd}	04.80 ^{ef}	01.40 ^{c}	02.70 ^{d}	08.80 ^{de}	13.60^{ab}	00.62 ^{d}
	±0.49	±0.44	±0.36	±0.57	±0.12	±1.92	±0.91	±0.35	±0.34	±0.17
T_8 – FO 3 %	19.70 ^{bc}	11.20 ^{cd}	38.50 ^{bcde}	11.90^{a}	03.00 ^{cd}	09.10 ^{f}	05.90 ^{g}	18.10 ^{f}	12.10^{a}	01.50 ^{f}
	±0.74	±0.33	±1.08	±0.32	±0.38	±0.27	±0.70	±0.49	±0.38	±0.23
T_9 – LO 3%	14.60^{a}	08.50^{a}	44.70 ^{f}	22.40 ^{f}	07.85 h	01.50 ^{c}	01.60 ^{bc}	09.30 ^{de}	22.70 ^{f}	00.41 ^{bc}
	±0.45	±0.24	±0.28	±0.35	±0.68	±0.32	±0.38	±0.54	±0.35	±0.13
T_{10} – RO 3%	19.50 ^{bcd}	12.00 ^{cde}	39.60 ^{bcde}	17.40^{de}	05.10 ^{fg}	01.70 ^{c}	02.50 ^{cd}	09.00 ^{de}	17.70 ^{de}	00.45 ^{bcd}
	±0.43	±0.40	±0.38	±0.26	±0.46	±0.09	±0.50	±0.18	±0.27	±0.40
T_{11} – (FO + 1 %	24.60 ^{e}	14.20 ^{g}	34.50^{ab}	17.10 ^{de}	02.10 ^{bc}	01.30 ^{c}	03.60 ^{de}	07.20 ^{cd}	16.90 ^{de}	00.42 ^{bc}
LO + RO)	±0.41	±0.12	±0.10	±0.26	±0.10	±0.27	±0.11	±0.18	±0.28	±0.13
T_{12} – (FO + LO	22.10 ^{cde}	12.30 ^{defg}	37.50^{abcd}	19.80 ^{ef}	02.30 ^{bc}	01.00 ^{bc}	03.70 ^{ef}	07.50 ^{d}	19.70 ^{ef}	00.38 ^{b}
+ RO) 2 %	±0.47	±0.33	±0.42	±0.56	±0.35	±0.13	±0.52	±0.51	±0.54	±0.13
T_{13} – (FO + LO	23.60 ^{de}	12.70 ^{defg}	36.70^{abc}	16.80 ^{cde}	03.90 ^{de}	01.50 ^{c}	04.40 ^{efg}	10.00 ^{e}	16.90 ^{cde}	00.59 ^{cd}
+ RO) 3 %	±0.50	±0.49	±0.17	±0.39	±0.69	±0.23	±0.56	±0.73	±0.35	±0.21

FO, fish oil; LO, linseed oil; RO, rapeseed oil. Mean values not sharing a common superscript columnwise differ significantly (P< 0.01).

thigh muscles and broilers that received 3% FO had higher values of total n-3 FAs than any other treatment groups. 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 (liver, adipose, thigh, breast and heart) lipids and Matthias *et al.* (2005) reported that feeding of fish oil resulted in higher accumulation of long chain omega -3- fatty acids (EPA, DHA) in the body tissues (breast and thigh). Mirghelenj *et al.* (2009) observed that supplementation of fish oil (0–5%) in broiler diet resulted in deposition of long chain n-3 fatty acids EPA and DHA in thigh and breast, were increased significantly (P<0.05) as the level of added fish oil increased (0–5%) in the broiler ration, which coincides with the present study. The amounts of total polyunsaturated fatty acids (LNA, EPA, DHA) were significantly (P<0. 001) increased when FO level (0–3%) was increased in the breast tissue (Said *et al.* 2008). Similarly, Saleh *et al.* (2009) supplemented the basal diet with 1.5%, 3% and 6% fish oil which caused 3, 14 and 60 folds increase in levels of LNA, EPA and DHA, respectively in the meat of broilers compared to the control group. Ali *et al.* (2012) found that addition of 5% fish oil in broiler diet significantly (P<0.01) increased the concentration of n-3 fatty acids in breast (22.90%) and thigh (18.10%) muscle, which is in agreement with the present study. Fish oil is one of the primary producers of long chain poly unsaturated fatty acids and these are capable of converting LNA to EPA and DHA, by a series of desaturations and elongations.

In this biological experiment, supplementation of linseed oil at 3% recorded higher linolenic acid content in breast and thigh muscle of broilers. Similar results were reported by Surekha *et al.* (2011) that broilers fed with linseed oil at 4% have increased (0.79%) linolenic acid in breast muscle due to presence of higher content of linolenic acid in linseed oil. Incorporation of rapeseed oil at graded levels increased the total n-3 fatty acids content in breast and thigh muscles of broiler in this study. According to Stanacev *et al.* (2014), there was a significant (P<0.05) increase of total n-3 fatty acids in the chicken breast meat fed with rapeseed oil (4 and 6%).

The n-3: n-6 ratio of polyunsaturated fatty acids was higher in the fish oil-fed groups compared to the control (P<0.01). This effect resulted from the existence of higher levels of n-3 and decreasing levels of n-6 in the broiler meat. Combination of fish, linseed and rapeseed oils resulted in

Table 6. Mean (±SE) values of organoleptic evaluation on breast and thigh meat of broilers at seventh week of age as influenced by various n-3 lipid sources in feed

Treatment groups	Appearance		Juiciness		Flavour		Tenderness		Overall acceptability	
	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh
T_1 – Control	5.83±0.31	5.67±0.56	5.67±0.33	6.00±0.37	6.17±0.65	5.00±0.52	5.50±0.62	5.67±0.33	5.33±0.42	5.50±0.22
T_2 – Fish oil (FO) 1%	6.50±0.43	6.00±0.82	6.33±0.42	6.33±0.71	6.83±0.48	5.67±0.42	5.83±0.48	5.33±0.49	6.33±0.33	5.67±0.42
T_3 – Linseed oil (LO) 1%	5.67±0.21	5.67±0.56	4.17±0.31	6.17±0.31	4.83±0.48	5.50±0.67	4.67±0.76	5.67±0.42	4.83±0.48	5.67±0.21
T_4 – Rapeseed oil (RO) 1%	4.83±0.48	5.83±0.95	4.50±0.40	5.50±0.50	5.50±0.76	4.67±0.71	4.67±0.42	5.67±0.49	5.17±0.48	5.17±0.60
T_5 – Fish oil 2%	6.50±0.67	5.17±0.83	5.83±0.31	4.50±0.56	5.67±0.42	5.83±0.91	5.50±0.34	4.50±0.43	5.83±0.40	4.83±0.75
T_6 – Linseed oil 2%	6.17±0.54	6.00±0.63	6.67±0.33	5.33±0.56	6.67±0.42	6.00±0.82	6.33±0.33	5.00±0.52	6.50±0.50	5.17±0.48
T_7 – Rapeseed oil 2%	6.17±0.54	5.67±0.42	4.67±0.42	5.67±0.42	6.17±0.60	5.83±0.54	5.00±0.58	5.33±0.67	5.33±0.33	5.00±0.37
T_8 – Fish oil 3%	7.33±0.33	5.17±0.60	6.00±0.45	4.67±0.71	6.50±0.34	4.67±0.61	6.67±0.21	5.00±0.52	6.33±0.33	4.67±0.56
T_9 – Linseed oil 3%	5.67±0.42	5.50±0.34	5.50±0.34	6.00±0.37	5.83±0.31	6.67±0.49	5.83±0.48	5.83±0.54	5.17±0.60	5.00±0.52
T_{10} – Rapeseed oil 3%	6.17±0.48	5.83±0.31	5.50±0.34	5.17±0.60	5.50±0.56	6.17±0.48	5.33±0.49	5.83±0.60	5.10±0.43	5.00±0.37
T_{11} – (FO + LO + RO) 1%	5.33±0.42	6.00±0.37	5.50±0.72	5.67±0.33	5.33±0.33	4.83±0.60	5.67±0.56	5.83±0.40	5.17±0.48	5.17±0.40
T_{12} – (FO + LO + RO) 2%	5.67±0.49	6.00±0.45	5.00±0.58	5.50±0.50	5.67±0.42	5.67±0.33	5.17±0.31	5.33±0.42	5.33±0.42	5.67±0.21
T_{13} – (FO + LO + RO) 3%	4.67±0.33	5.33±0.56	5.33±0.49	5.50±0.56	5.50±0.43	4.83±0.54	6.33±0.42	5.83±0.40	5.33±0.49	5.17±0.31

FO, fish oil; LO, linseed oil; RO, rapeseed oil.

significant (P<0.01) increase of total n-3 fatty acids in breast and thigh muscles. Similar result was reported by Konieczka *et al*. (2012) that combination of fish, linseed and rapeseed oils in broiler ration resulted in significant (P<0.01) deposition of total n-3 fatty acids in breast and thigh meat.

The appearance, juiciness, flavour, tenderness and overall acceptability did not get altered significantly due to incorporation of n-3 lipid sources at graded level in broiler diets. 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. Konieczka *et al.* (2012) who supplemented chicken diets with fish, linseed and rapeseed oils reported that meat of chickens administered with these fats was characterized by less desirable sensory attributes. Contrary to the report, incorporation of fish, linseed and rapeseed oils independently and simultaneously upto three per cent levels did not show deterioration in sensory quality of cooked meat and taste panelist accepted the quality in this study. Marco *et al*. (2013) reported that supplementation of omega-3- feed at graded levels (1, 2, 3 and 4%) did not affect the organoleptic characteristics (flavour, off-flavour, tenderness, juiciness and general acceptability) of broiler meat which is in agreement with the results of this study.

From the results of the present study, incorporation of omega-3-fatty acids sources in poultry diets would increase deposition of beneficial fatty acids in the poultry carcass. Fish, linseed and rapeseed oils in broiler diet are a good source of omega-3-fatty acids for the enrichment of LNA, EPA and DHA content of poultry meat with no adverse effect on meat quality in terms of organoleptic assessment.

REFERENCES

Ali A S, Hossein I, Mohammadamir K T and Mohammad C. 2012. Fatty acids profiles in meat of broiler chicks fed diet containing corn oil switched to fish oil at different weeks of age. *World Applied Sciences Journal* **18**: 159–65.

Arumugam M P and Panda B. 1970. Processing and inspection of poultry. Indian Veterinary Research Institute, Izatnagar, U.P.

Folch J, Lees M and Stanely G H S. 1957. A simple method for the isolation and purification of total lipids from animal tissues. *The Journal of Biological Chemistry* **226**: 497–507.

Galli C, Simopoulos A P and Tremoli E. 1994. Fatty acids and lipids: Biological aspects. *World review of Nutrition and Dietetics* **75**: 1–197.

Kinsella J E, Lokesh B and Stone R A. 1990. Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular

disease: Possible mechanisms. *American Journal of Clinical Nutrition* **52**: 1–28.

Konieczka P, Kostyra E, Swiderski F, Czerwinski J and Smulikowska S. 2012. Sensory characteristics of meat from broiler chickens fed diets containing rapeseed, linseed and fish oil. *XXIV International Poultry Symposium* PB WPSA: Science for poultry practice – poultry practice for science, 12–14.09.2012 Ko³obrzeg, p. 29.

Lopez-Ferrer S, Baucells M D, Barroeta A C and Grashorn M A. 1999. n-3 enrichment of chicken meat using fish oil: Alternative substitution with rapeseed and linseed oils. *Poultry Science* **78**: 356–65.

Marco D J M, Acda S P, Roxas D B and F E Merca. 2013. Effect of omega-3 fatty acid enriched feed supplement on broiler performance and carcass quality. *Philippine Journal of Veterinary and Animal Sciences* **39**: 53–62.

Matthias S, Howard W H, Ebrahim R F, Josef B and Renata G M. 2005. Effect of different sources of dietary omega-3 fatty acids on general performance and fatty acid profiles of thigh, breast, liver and portal blood of broilers. *Journal of the Science of Food and Agriculture* **85**: 219–26.

Miller D and Robisch P. 1969. Comparative effect of herring, menhaden and safflower oils on broiler tissues, fatty acid composition and flavour. *Poultry Science* **48**: 2146–57.

Mirghelenj S A, Golian A and Taghizadeh V. 2009. Enrichment of chicken meat with long chain omega-3 fatty acids through dietary fish oil. *Research Journal of Biological Sciences* **4**: 604–08.

Panda B, Pandey N K, Mahapatra C M, Verma S S, Shrivastav A K and Chaudhuri D. 1982. *Laboratory manual on post harvest technology of avian products*. Avian products technology section, Central Avian Research Institute, Izatnagar, Uttar Pradesh, India.

Said C A, Habib A S, Naser M S, Ali R A and Tohid V. 2008. Omega-3 fatty acids enrichment and organoleptic characteristics of broiler meat. *Asian Journal of Animal and Veterinary Advances* **3**: 62–69.

Saleh H, Rahimi S and Karimi Torshizi M A. 2009. The effect of diet that contained fish oil on performance, serum parameters, the immune system and the fatty acid composition of meat in broilers. *International Journal of Veterinary Research* **3**: 69–75.

Snedecor G W and Cochran W C. 1989. *Statistical Methods*. 8th edn. Iowa State University Press, Ames, Iowa, USA.

Stanacev V Z, Milosevic S, Pavlovski Z, Milic D, Vranjes M V, Puvaca N and Stanacev V S. 2014. Effects of dietary soybean, flaxseed and rapeseed oil addition on broilers meat quality. *Biotechnology in Animal Husbandry* **30**: 677– 85.

Sukhija P S and Palmquist D L. 1988. Rapid method for determination of total fatty acid content and composition of feedstuffs and feces. *Journal of Agricultural and Food Chemistry* **36**: 1202–06.

Surekha B, Mahabaleshwar H, Ajit R, Deepashree D and Shivajirao K. 2011. Studies in the production of omega- 3-enriched chicken meat: 1. *Indian Journal of Poultry Science* **46**: 40–45.