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Original Research Article

Effect of dietary incorporation of n-3 polyunsaturated fatty acids rich oil sources on fatty acid profile, keeping quality and sensory attributes of broiler chicken meat

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ABSTRACT

The present study was undertaken to investigate the effect of dietary replacement of commonly used vegetable oil (sunflower oil, SFO) with n-3 polyunsaturated fatty acids (PUFA) rich oil sources on broiler chicken performance, carcass yield, meat fatty acid composition, keeping quality and sensory attributes of meat. In the current experiment, 300 day-old Krishibro broiler chicks were randomly distributed to 5 dietary groups (50 replicates with 6 chicks in each) prepared by replacing SFO (2% and 3% of diet during starter and finisher periods, respectively) with n-3 PUFA rich soybean oil (SO), mustard oil (MO), linseed oil (LO) or fish oil (FO) on weight basis. Variation in oil sources had no influence ($P > 0.05$) on performance and carcass yield. Supplementation of MO, LO or FO significantly ($P < 0.01$) increased the n-3 PUFA, lowered the n-6 PUFA deposition and n-6:n-3 ratio in breast and thigh without affecting the organoleptic characters (appearance, flavour, juiciness, tenderness and overall acceptability) of meat. However, thiobarbituric acid reacting substances concentration in meat was increased ($P < 0.01$) with LO and FO supplementation compared with SFO. It is concluded that, dietary incorporation of MO, LO or FO at 2% and 3% levels during starter and finisher phase can enrich broiler chicken meat with n-3 PUFA without affecting the bird's performance and sensory characters of meat.

1. Introduction

The results of recent worldwide research suggest that, dietary and lifestyle factors contribute to the development of many non-infectious diseases, including obesity, cardiovascular and degenerative diseases (Bosma-den Boer et al., 2012; Chakma and Gupta, 2014). Using of pharmaceutical drugs is one of the basic ways to overcome these dietary/lifestyle born disorders; however, this approach makes consumers feel psychologically sick. Hence, consumers are now looking for the food products that provide value beyond nutrition (Bigliardi and Galati, 2013) instead of pharmaceutical drugs. To overcome this problem, the present study targets in developing functional foods, which can be consumed as food, not as capsules. Functional foods defined as “designed to have physiological benefits and/or reduce the risk of chronic disease beyond basic nutritional functions, and may be similar in appearance to conventional foods and consumed as a part of regular diet” (ARS, 2010).

Eicosapentaenoic acid (20:5, n-3; EPA), docosahexaenoic acid (22:6, n-3; DHA) and α-linolenic acid (18:3, n-3; LNA) are important n-3 polyunsaturated fatty acids (PUFA) in human nutrition, moreover LNA serves as a precursor for synthesis of EPA and DHA (Simopoulos, 2008). The interest on n-3 PUFA and balance of n-3 to n-6 fatty acids (approximately 2:1) in human diet is gaining momentum due to their roles in reducing the incidence of lifestyle diseases such as coronary artery diseases, hyper tension and

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diabetes, as well as some auto immune and inflammatory diseases, and modern diets are imbalance in n-6/n-3 PUFA (>10:1) ratio which is one of the major reasons of various lifestyle disorders (Simopoulos, 2008). Modification of dietary fatty acids composition is one of the most efficient ways to enhance the accumulation of desired PUFA in the chicken meat (Bhalerao et al., 2014). Enrichment of most commonly consumed broiler chicken meat through dietary modification, apart from providing health benefits to consumers (consumption of PUFA enriched meat), has added advantage of increasing bird's health too.

Thus, the proposed study was undertaken to investigate the effect of dietary replacement of commonly used vegetable oil (sunflower oil, SFO) with n-3 PUFA rich (soybean oil [SO], mustard oil [MO], linseed oil [LO] and fish oil [FO]) oil sources on broiler chicken carcass yield, meat fatty acid composition, keeping quality and sensory attributes of meat.

2. Material and methods

2.1. Birds, management and diets

A total of 300 day-old broiler chicks (Krishibro) were randomly distributed to 50 replicates with 6 birds in each, further these replicates were randomly allotted to 5 dietary treatments with 10 replicates in each. Birds were reared on raised wire floor battery brooder in open side houses. The brooder temperature was maintained at 34 ± 1 °C up to 7 days of age and gradually reduced to 26 ± 1 °C by 21 days of age after which, chicks were maintained at room temperature. A corn-soybean meal based basal diet (BD) was formulated and used in the current experiment. Control starter (0 to 3 wk) and finisher (4 to 6 wk) diets were formulated using SFO (Table 1). Subsequently, 4 experimental diets were formulated in which SFO was replaced by SO, MO, LO and FO. Fatty acid composition of basal diet and experimental oils are presented in Table 2. The birds were offered respective diets *ad libitum* throughout the experimental period of 42 days. The oils used in the study were procured from the local traders in Hyderabad, Telangana, India. Uniform management and vaccination schedule were followed for all the birds. The experiment was conducted following the guidelines of the animal ethical committee of the institute.

Table 1
Ingredient and nutrient composition of experimental diets (DM basis).

Item	Starter (0 to 3 wk)	Finisher (4 to 6 wk)
Ingredient, %		
Maize	56.10	58.02
Soybean meal	36.34	34.70
$CaHPO_4$	1.88	1.62
Stone grit	1.67	1.71
NaCl	0.40	0.40
DL-methionine	0.21	0.20
Choline chloride 50%	0.10	0.06
Sunflower oil[1]	2.00	3.00
Vitamin premix[2]	0.05	0.04
Mineral premix[3]	0.10	0.10
Toxin binder	0.10	0.10
Antibiotics	0.05	0.05
Nutrient composition, % (calculated values)		
ME, MJ/kg	12.16	12.59
Protein	21.97	20.06
Lysine	1.21	1.07
Methionine	0.53	0.50
Available phosphorous	0.45	0.40
Calcium	0.90	0.85

[1] Further experimental diets were formulated by replacing sunflower oil with n-3 polyunsaturated fatty acids (PUFA) rich oils on weight basis.
[2] Supplies per kg diet: vitamin A, 16,500 IU; vitamin D_3, 3,200 ICU; vitamin E, 12 mg; vitamin K, 2 mg; vitamin B_1, 1.2 mg; vitamin B_2, 10 mg; vitamin B_6, 2.4 mg; vitamin B_{12}, 12 μg; niacin, 18 mg; pantothenic acid, 12 mg.
[3] Supplies per kg diet: Mn, 90 mg; Zn, 72 mg; Fe, 60 mg; Cu, 10 mg; I, 1.2 mg.

Table 2
Fatty acid composition (% of total fatty acids) of basal diet and experimental oils.[1]

Fatty acid	BD	SFO	SO	MO	LO	FO
LA (C18:2n-6)	50.03	62.42	46.14	13.26	11.92	1.67
AA (C20:4n-6)	0.21	0.30	0.12	0.06	0.24	0.00
LNA (C18:3n-3)	2.36	0.90	7.29	11.26	52.52	0.84
EPA (C20:5n-3)	0.03	0.07	0.01	0.16	0.00	13.66
DHA (C22:6n-3)	0.00	0.10	0.00	0.14	0.10	17.98
∑SFA	15.61	11.46	15.28	17.44	14.58	31.95
∑MUFA	29.67	24.12	29.07	56.52	19.46	26.26
∑PUFA	54.79	64.42	55.65	26.04	65.96	35.79
∑n6	51.29	64.05	47.19	11.36	12.34	2.45
∑n3	3.12	1.01	7.82	13.88	53.12	32.89
n6:n3	16.43	62.43	6.03	0.85	0.23	0.07

BD = basal diet; SFO = sunflower oil; SO = soybean oil; MO = mustard oil; LO = linseed oil; FO = fish oil; LA = linoleic acid; AA = arachidonic acid; LNA = linolenic acid; EPA = eicosapentaenoic acid; DHA = docosahexaenoic; MUFA = mono unsaturated fatty acid; SFA = saturated fatty acid; PUFA = poly unsaturated fatty acid; ∑ = Total.
[1] Each value is an average of 2 observations.

2.2. Performance, carcass yield, meat fatty acid composition and quality

At the end of experiment, individual body weight of chicks, replicate wise feed intake were recorded to know the body weight gain (BWG), feed intake (FI), respectively, and feed conversion ratio (FCR) was calculated as a ratio between feed consumed and weight gained. On day 43, 8 birds from each dietary group were randomly selected, starved overnight and sacrificed on the following day to evaluate the dressing yield expressed as a percentage of pre-slaughter body weight. From slaughtered birds, livers and approximately 20 g of breast and thigh muscle samples were collected in 2 sets in a sealed polythene bag and preserved at −20 °C for further laboratory analysis. First set of meat samples were used for analysis of fatty acid composition, and second set of meat and liver samples were frozen at −20 °C for sensory evaluation of meat, crude protein (AOAC, 2012; method No. 954.01) percentages and keeping quality (lipid peroxidation development) in meat and liver. Pressure-cooked meat without salt was organoleptically evaluated by semi trained judges on a 8-point Hedonic scale (Peryam and Pilgrim, 1957) (Table 3). The lipid peroxidation of meat was estimated by quantification of malonaldehyde (MDA) value using the thiobarbituric acid reactive substances (TBARS) concentration as per procedure described by Balasubramanian et al. (1988).

2.3. Estimation of fatty acid profile

The fatty acid profiles of BD, SFO, SO, MO, LO and FO breast and thigh meat (wet or as such samples) were analysed by following, AOAC (2012), Method No. 969.33, using gas chromatography (GC) (GC-FID, Agilent -7820A) equipped with an automatic injector.

Aliquot (1 μL) was injected into a capillary column (HP-88, 100 m × 0.25 mm × 0.2 μm) with cyanopropyl methyl silicone as stationary phase. Nitrogen was used as carrier gas at a constant flow rate of 1 mL/min in the column. The split ratio was 30:1. The operating conditions of GC were as followed: initial temperature was 140 °C (5 min), increasing at 4 °C/min to reach 240 °C and maintained for 15 min. Total time of chromatograph was 35 min. Air flow and hydrogen flow were 300 and 30 mL/min, respectively. Detector (flame ionized detector) temperature was 280 °C. Fatty acids peaks were identified by comparison with retention time of fatty acid methyl esters standards (Sigma–Aldrich). Quantification

Table 3
Description of the scale to test sensory qualities of meat.

Score	Appearance	Flavour	Juiciness	Texture/tenderness	Overall acceptability
1	Extremely poor	Extremely poor	Extremely dry	Extremely undesirable	Extremely unacceptable
2	Very poor	Very poor	Very dry	Very undesirable	Very unacceptable
3	Moderately poor	Moderately poor	Moderately dry	Moderately undesirable	Moderately unacceptable
4	Slightly poor	Slightly poor	Slightly dry	Slightly undesirable	Slightly unacceptable
5	Fair	Fair	Slightly juicy	Slightly desirable	Slightly acceptable
6	Good	Good	Moderately juicy	Moderately desirable	Moderately acceptable
7	Very good	Very good	Very juicy	Very desirable	Very acceptable
8	Excellent	Excellent	Extremely juicy	Extremely desirable	Extremely acceptable

was made by internal standard and by using the HP chemstation software.

2.4. Statistical analysis

The obtained data were statistically analysed by one-way ANOVA as completely randomized design using statistical package for social sciences (SPSS) 16th version. The means were compared by Duncan's multiple range test (1955). Significance was considered at $P < 0.05$.

3. Results

3.1. Carcass yield and meat protein content

Dietary replacement of SFO with SO, MO, LO and FO had no influence ($P > 0.05$) on overall performance (BWG, FI and FCR) and dressed yield (Table 4). Similarly, protein percentage in breast meat, thigh meat and liver was comparable among the dietary treatments (Table 4).

3.2. Fatty acid composition of meat

The fatty acid composition of breast and thigh meat of birds fed diets incorporated with various oil sources is presented in Table 5. Dietary incorporation of MO, LO and FO significantly ($P < 0.05$) lowered the linoleic acid (LA) content in both breast (SFO > SO > MO ≥ LO ≥ FO) and thigh meat (SFO = SO > MO > LO = FO) compared with SFO. Similarly, SO incorporation lowered the LA content in breast meat compared with SFO, but not in thigh meat.

The arachidonic acid (AA) content in both breast and thigh meat did not differ significantly among the dietary treatments. Dietary replacement of SFO with n-3 PUFA rich oil sources (SO, MO, LO and FO) significantly ($P < 0.05$) improved the linolenic acid (LNA) content in both breast (SFO < SO < MO < LO = FO) and thigh meat (SFO < SO < MO < FO < LO). In breast meat, percentage of LNA deposition was higher with LO and FO supplementation compared with other oil sources. However, in thigh meat, the highest percent LNA deposition was recorded with LO compared with other dietary treatments. Further, LO and FO supplementation significantly ($P < 0.01$) increased the eicosapentaenoic acid (EPA) deposition in breast meat compared with other dietary treatments (SFO = SO = MO < LO < FO). In thigh meat, MO, LO and FO supplementation improved ($P < 0.01$) EPA deposition compared with SFO (SFO ≤ SO ≤ MO < LO < FO). The EPA levels in thigh meat were increased ($P < 0.01$) with MO supplementation compared with SFO but this improvement was not observed in breast meat. Docosahexaenoic (DHA) contents in both breast and thigh meat (SFO = SO < MO < LO < FO) were significantly ($P < 0.01$) increased with MO, LO and FO supplementation compared with SFO and SO. Moreover, the highest ($P < 0.01$) EPA and DHA levels in both breast and thigh meat were recorded with FO supplementation.

In the current investigation, variation in dietary oil source did not influence ($P > 0.05$) the mono unsaturated fatty acids (MUFA) deposition in the breast and thigh meat. Similarly, dietary replacement of SFO with SO and MO had no significant influence on saturated fatty acids (SFA) levels in the meat (breast and thigh), but incorporation of FO or LO in place of SFO, significantly ($P < 0.01$) lowered the SFA deposition in breast (SFO = SO = MO < LO = FO) and thigh (SFO = SO ≤ MO ≤ LO = FO) meat. The PUFA were increased ($P < 0.01$) in both breast and thigh meat with dietary incorporation of FO and LO in place of SFO. Whereas, dietary replacement of SFO with SO and MO could not alter ($P > 0.05$) the total PUFA content in breast (SFO = SO = MO < LO = FO) and thigh (SFO = SO ≤ MO ≤ LO = FO) meat. In breast and thigh meat, total n-6 PUFA content was lowered with FO or LO supplementation compared with SFO and the total n-6 PUFA in thigh meat was comparable among the birds supplemented with SFO, SO or MO, but in breast meat, SO or MO supplementation lowered ($P < 0.01$) the total n-6 PUFA deposition compared with SFO. Dietary replacement of SFO with n-3 PUFA rich oil sources significantly ($P < 0.01$) improved the total n-3 PUFA in breast and thigh meat (SFO < SO < MO < LO < FO). The highest total n-3 PUFA deposition in both breast and thigh meat was recorded with FO supplementation. Lowered ($P < 0.01$) n-6:n-3 ratio in breast and thigh meat

Table 4
Effect of dietary incorporation of n-3 polyunsaturated fatty acids (PUFA) rich oil sources on performance, protein contents in breast and thigh meat and liver (as such basis).

Oil source	Overall performance			Dressing yield, %	Protein, %		
	BWG, g	FI, g	FCR		Breast	Thigh	Liver
Sunflower oil	1,388	2,950	2.13	71.92	18.95	18.47	21.64
Soybean oil	1,384	2,863	2.07	72.40	18.77	18.04	21.85
Mustard oil	1,368	2,932	2.15	71.01	19.16	17.88	22.13
Linseed oil	1,396	2,898	2.08	70.68	19.11	17.29	21.80
Fish oil	1,324	2,748	2.08	71.42	18.16	17.35	22.19
SEM	13.16	27.71	0.02	0.28	0.22	0.23	0.17
P-value	0.439	0.150	0.421	0.30	0.45	0.08	0.06

BWG = body weight gain; FI = feed intake; FCR = feed conversion ratio; SEM = standard error of mean.

Table 5
Effect of dietary incorporation of n-3 polyunsaturated fatty acids (PUFA) rich oil sources on fatty acid profile (% of total fatty acids) in breast and thigh meat of broiler chickens (as such basis).

Fatty acid	SFO	SO	MO	LO	FO	SEM	*P*-value
Breast							
LA (C18:2n-6)	23.02^{a}	20.68^{b}	19.10^{c}	18.30^{cd}	17.05^{d}	0.40	0.01
AA (C18:3n-3)	0.11	0.13	0.09	0.09	0.07	0.01	0.34
LNA (C20:4n-6)	0.23^{d}	0.92^{c}	3.23^{b}	5.02^{a}	4.60^{a}	0.34	0.01
EPA (C20:5n-3)	0.17^{c}	0.25^{c}	0.63^{c}	1.74^{b}	2.72^{a}	0.18	0.01
DHA (C22:6n-3)	0.23^{d}	0.63^{d}	1.47^{c}	3.51^{b}	5.76^{a}	0.35	0.01
Total MUFA	31.04	30.57	30.96	30.64	30.80	0.45	1.00
∑SFA	43.91^{a}	43.96^{a}	43.39^{a}	39.84^{b}	37.65^{b}	0.69	0.01
∑PUFA	25.05^{b}	24.04^{b}	25.65^{b}	29.53^{a}	31.55^{a}	0.65	0.01
∑n6	23.49^{a}	21.23^{b}	19.41^{c}	18.56^{cd}	17.37^{d}	0.41	0.01
∑n3	0.82^{e}	2.00^{d}	5.61^{c}	10.61^{b}	13.34^{a}	0.80	0.01
n6:n3	23.88^{a}	11.31^{a}	3.52^{b}	1.82^{b}	1.32^{b}	1.41	0.01
Thigh							
LA (C18:2n-6)	23.28^{a}	22.63^{a}	20.25^{b}	18.81^{c}	17.33^{c}	0.79	0.01
AA (C18:3n-3)	0.13	0.14	0.09	0.08	0.07	0.01	0.10
LNA (C20:4n-6)	0.35^{e}	1.19^{d}	3.39^{c}	5.68^{a}	4.39^{b}	0.34	0.01
EPA (C20:5n-3)	0.10^{d}	0.31^{cd}	0.72^{c}	1.78^{b}	2.37^{a}	0.16	0.01
DHA (C22:6n-3)	0.08^{d}	0.63^{d}	1.57^{c}	2.70^{b}	5.27^{a}	0.31	0.01
∑MUFA	32.86	32.60	31.53	32.54	32.18	0.35	0.99
∑SFA	42.21^{a}	42.44^{a}	39.89^{ab}	37.20^{b}	37.30^{b}	0.71	0.02
∑PUFA	24.93^{b}	25.06^{b}	27.57^{ab}	30.25^{a}	30.52^{a}	0.64	0.01
∑n6	23.41^{a}	23.18^{a}	20.35^{ab}	18.89^{b}	17.67 ^{b}	0.57	0.01
∑n3	1.18^{e}	2.44^{d}	6.56^{c}	10.49^{b}	12.21^{a}	0.71	0.01
n6:n3	20.19^{a}	9.79^{a}	3.14^{b}	1.81^{b}	1.46^{b}	1.18	0.01

SFO = sunflower oil; SO = soybean oil; MO = mustard oil; LO = linseed oil; FO = fish oil; LA = linoleic acid; AA = arachidoinic acid; LNA = linolenic acid; EPA = eicosapentaenoic acid; DHA = docosahexaenoic; MUFA = mono unsaturated fatty acid; SFA = saturated fatty acid; PUFA = poly unsaturated fatty acid; ∑ = Total; SEM = standard error of mean.
$^{a-e}$ Means with different superscripts in a row differ significantly ($P < 0.05$).

was observed with MO, LO and FO supplementation compared with SFO or SO.

3.3. Keeping quality

In breast meat, the highest ($P < 0.01$) TBARS concentration (nmol MDA/mg protein), was noticed with FO supplementation compared with other dietary treatments, in which TBARS concentration was statistically comparable (FO > SFO = SO = MO = LO). In thigh meat, dietary incorporation of MO, LO and FO significantly ($P < 0.05$) increased TBARS concentration compared with control group (SFO), however, TBARS concentration in liver was not influenced by dietary incorporation of PUFA rich oils (Table 6).

3.4. Organoleptic characters of meat

The sensory attributes of meat in terms of appearance, flavour, juiciness, tenderness and overall acceptability were not influenced ($P > 0.05$) by replacing the SFO with n-3 PUFA rich oil sources (SO, MO, LO or FO) (Table 7).

Table 6
Effect of dietary incorporation of n-3 polyunsaturated fatty acids (PUFA) rich oil sources on keeping quality (thiobarbituric acid reacting substances [TBARS] concentration, nmol MDA/mg protein).

Oil source	Breast	Thigh	Liver
Sunflower oil	1.95^{b}	1.54^{d}	1.43
Soybean oil	2.14^{b}	1.97^{cd}	1.31
Mustard oil	1.88^{b}	2.80^{bc}	1.37
Linseed oil	1.72^{b}	3.13^{b}	2.00
Fish oil	3.30^{a}	4.31^{a}	1.84
SEM	0.17	0.21	0.14
P-value	0.01	0.01	0.43

MDA = malonaldehyde; SEM = standard error of mean.
$^{a-d}$ Means with different superscripts in a row differ significantly ($P < 0.05$).

4. Discussion

4.1. Performance, carcass yield and meat protein content

The present results on overall performance and carcass yield are in agreement with the findings of Lopez-Ferrer et al. (2001a,b) and Poorghasemi et al. (2013), who observed no effect on performance and carcass yields due to dietary incorporation of LO, FO and MO up to 4% level in the broiler chicken diet. Similarly, no effect on carcass yield of broilers was observed with dietary inclusion of LO (Panda et al., 2015) or FO (Chekani-Azar et al., 2008 and Panda et al., 2016) at 3% level. Nobakht et al. (2011) also observed no significant effect on carcass yield of broilers due to dietary replacement of SFO with SO or MO on weight basis (4% of diet).

Similar to present findings, Crespo and Esteve-Garcia (2001) found no influence of dietary fat type on protein content of breast and thigh muscle. Zelenka et al. (2006) also noticed no variation in protein content of breast and thigh meat due to dietary incorporation of LO up to 7% in broiler chicken diet.

4.2. Fatty acid composition of meat

It has been reported that, fatty acid composition of broiler meat can be altered by modifying the dietary fatty acid composition (Lopez-Ferrer et al., 2001a,b; Shin et al., 2011). This might be the reason for increase in LNA content in the meat by incorporating the LNA rich oil sources (MO, LO and FO) (Table 2) in the broilers' diet. In addition to this, the highest LNA content was recorded in thigh meat with LO supplementation, which might be due to higher LNA content in LO compared with other oils (SFO, SO, MO and FO) used in current research (Bhalerao et al., 2014) (Table 2). In agreement with present findings, Zelenka et al. (2008a) reported that, dietary incorporation of LO significantly increased the LNA content in the broiler chicken meat.

Furthermore, dietary incorporation of EPA and DHA rich FO, compared with other experimental oils (SFO, SO, MO and LO) (Bhalerao et al., 2014) (Table 2), might have altered the fatty acid composition of meat (Shin et al., 2011) and enhanced their contents in the meat compared with other oil sources. Similarly, Huang et al. (2006) and Basmacıoğlu et al. (2004) observed increase in EPA and DHA levels in meat with dietary incorporation of FO. Moreover, incorporation of FO or LO in place of SFO, significantly lowered and increased the SFA and total PUFA deposition, respectively, in breast and thigh meat.

Dietary replacement of SFO with n-3 PUFA rich oil sources significantly improved the total n-3 PUFA in breast and thigh meat (SFO < SO < MO < LO < FO). The highest total n-3 PUFA deposition in both breast and thigh meat was recorded with FO supplementation. This might be due to dietary incorporation of n-3 PUFA oil sources which might have increased their deposition in the meat (Table 2; Bhalerao et al., 2014). Significantly increased n-3 PUFA and decreased n-6 PUFA with MO, LO and FO supplementation resulted in lowered n-6:n-3 ratio in breast and thigh meat with MO, LO and FO supplementation compared with SFO or SO. The findings of present study are in consistent with the findings of Panda et al. (2015, 2016) who observed an increase in total PUFA and n-3 fatty acid and a decrease in n-6:n-3 ratio and SFA levels in breast and thigh meat with dietary replacement of SFO with LO in broiler chicken diet. Similarly several researchers noticed higher n-3 PUFA and lowered n-6:n-3 ratio due to dietary inclusion of MO (Salamatdoustnobar et al., 2010; Gallardo et al., 2012), LO (Lopez Ferrer et al., 2001b; Zelenka et al., 2008a) or FO (Lopez-Ferrer et al., 2001a; Huang

Table 7
Effect of dietary incorporation of n-3 polyunsaturated fatty acids (PUFA) rich oil sources on sensory attributes of broiler chickens meat.

Oil source	Appearance	Flavour	Juiciness	Tenderness	Overall acceptability
Sunflower oil	5.90	6.00	5.30	5.60	5.60
Soybean oil	6.00	5.90	5.40	5.50	5.90
Mustard oil	6.00	5.60	5.50	5.40	5.50
Linseed oil	5.90	5.80	6.00	5.70	5.50
Fish oil	5.50	6.00	5.70	5.80	5.50
SEM	0.17	0.17	0.16	0.17	0.15
P-value	0.89	0.95	0.70	0.96	0.91

SEM = standard error of mean.

et al., 2006). These PUFA enriched chicken meat with higher level of n-3 PUFA and lower n-6:n-3 ratio may promote the consumer health and prevent various lifestyle diseases (Grashorn, 2007), because in modern food habits, people are consuming more SFA rich and improper n-6:n-3 (>10:1) diets, which is one of the main reasons for various health disorders (Grashorn, 2007).

4.3. Keeping quality

Higher TBARS concentration with FO (breast and thigh meat) and LO, MO (breast meat) supplementation might be due to increased total PUFA content in meat, which might have favoured lipid peroxidation, thereby increased the MDA levels (TBARS concentration) in the meat (Wood et al., 2008). Rymer and Givens (2005) reported that, poultry meat with a higher concentration of LNA compared with LA will be more prone to oxidation, in addition to this, poultry meat with higher concentration of EPA and DHA will be more susceptible to oxidative damage. In current study, EPA and DHA values were the highest in chicken meat supplemented with FO (Table 5) and this might be another reason for higher TBARS concentration in chicken meat of bird fed on FO. The present results are in agreement with the finding of Hugo et al. (2009) and Saleh et al. (2010) who observed a significant increase in lipid oxidation levels (TBA values) in chicken meat (breast and thigh) with dietary inclusion of FO at 3% of diet. Similarly, Kralik et al. (2013) observed higher TBARS concentration in broiler chicken meat enriched with PUFA by dietary incorporation of LO at 3% of diet.

4.4. Organoleptic characters of meat

In consideration of consumer acceptance, enrichment of broiler chicken meat with n-3 PUFA or balancing of n-6:n-3 PUFA, without compromising the sensory attributes of meat is very essential. In the present study, sensory attributes of meat were not influenced due to dietary incorporation of n-3 PUFA oil sources. Current experiment results are in agreement with the findings of Zelenka et al. (2008b), Lopez-Ferrer et al. (2001b) and Panda et al. (2015) who observed no variation in meat sensory quality parameters due to incorporation of LO in the diet of broiler chickens at 7%, 4% and 3% levels, respectively. Similarly, Panda et al. (2016) observed no adverse effect on sensory attributes of chicken meat with dietary inclusion of FO up to 3%. Whereas, Huang et al. (2006) noticed a decrease in the flavour of breast meat of chicken with FO supplementation at 3% level, but they found no difference in overall acceptability of meat with FO supplementation. The results of our study suggested that PUFA rich oil sources such as MO, LO and FO can be used up to 3% without adversely affecting the sensory attributes of broiler chicken meat.

5. Conclusions

It can be concluded that, the dietary replacement of SFO with n-3 PUFA rich MO, LO or FO resulted in relatively high deposition of n-3 PUFA in chicken meat and lowered n-6:n-3 ratio without affecting the birds performance, dressing yield and sensory attributes of meat.

Conflict of interest

Authors declaring that, they do not have any competing of interest.

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