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Enrichment of Chicken Meat with Long Chain Omega-3 Fatty Acids through Dietary Fish Oil

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Abstract: An experiment was conducted to assess the effect of dietary added fish oil on performance, Fatty Acid (FA) composition and sensory traits of broiler chicken meat. Four hundred and fifty, 28 days old Ross, 308 male broiler chickens were divided into 30 groups of similar body weight of 15 birds each. Six grower isocaloric/isonitrogenous diets contained 0-5% fish oil were provided and each was fed to 5 groups of birds from 28-42 days of age. Production performance was measured weekly, whereas Fatty Acid (FA) profile of thigh and breast meat were determined in 3 chicken from each replicate at the end of experiment. There was not any significant effect ($p>0.05$) of dietary treatments on birds Feed Intake (FI), Body Weight Gain (BWG), Feed Conversion Ratio (FCR) and livability. The amount of long chain n-3 FAs (Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA)) in thigh and breast were increased significantly as the level of added fish oil increased in the diet ($p<0.05$), whereas linoleic acid (n-6) and alpha linolenic acid (n-3) content of this 2 cuts were not affected by the level of dietary fish oil ($p>0.05$). The breast and thigh meat from birds fed diets with 0, 1 and 2% fish oil were in the acceptable range (scores <2) to the panelists. The DHA content of breast and thigh of birds fed diet with 0-2% fish oil, increased from 0.046 and 0.086 (mg g^{-1}) to 0.166 and 0.27 (mg g^{-1}), respectively. A significant linear relationship was found between the levels of fish oil and EPA in breast fillet and thigh ($R^2 = 0.59$ and $R^2 = 0.71$, respectively) and also for DHA ($R^2 = 0.71$ and $R^2 = 0.72$, respectively).

Key words: Chicken meat, fish oil, omega-3 FA, meat quality, BWG, FCR

INTRODUCTION

N-3 fatty acids are essential for normal growth and development and may play an important role in prevention of coronary artery disease, hypertension, arthritis, other inflammatory and autoimmune disorders and cancer in human (Simopoulos, 1991). Fatty acid profile of broiler meat may be modified through dietary fish oil (Scaife *et al*., 1994; Lopez-Ferrer *et al*., 2001). When meat was enriched with polyunsaturated fatty acid particularly n-3 long-change fatty acids (C≥20), all vegetable oil sources showed to be less effective than marine oils, because marine oils composed of relatively high Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) content.

Vegetable oils contain Linolenic Acid (LNA), whose conversion to longer-chain derivatives and deposition in peripheral tissues is not sufficient to give nutritionally valuable modified products. Chickens modify their lipid profile shortly after 1 week of replacement of the dietary fat source and a linear response to increasing amounts of EPA and DHA in diet would ensure high levels of such fatty acids in meat (Lopez-Ferrer *et al*., 2001). However, the use of fish oil at concentrations >1-2% in poultry diets resulted in several organoleptic problems in the final product (Hargis and Van Elswyk, 1993). This experiment was conducted to study the effect of dietary Caspian Kilka fish oil on broiler chicken performance, fatty acid composition and sensory evaluation of meat tested by panelists from north of Iran.

MATERIALS AND METHODS

Animal housing and diets: Four hundred and fifty, 28 days of age, Ross 308 male broiler chickens were allocated to 6 isocaloric/isonitrogenous dietary treatments (Table 1) with 5 replicate of 15 birds each. The birds were reared in a controlled environmental house and had *ad-libitum* access to water and feed. All dietary nutrients were provided as of those recommended by the AVIAGEN. The Caspian Kilka fish oil was added at the levels of 0-5% to grower diets and fed from 28-42 days of age.

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Table 1: Composition of experimental grower diets fed to broiler chickens from 28-42 days of age

	Percentage of fish oil in diet					
Ingredients (%)	0 (control)	1	2	3	4	5
Corn grain	56.45	56.45	56.45	56.45	56.45	56.45
Soybean meal	34.13	34.13	34.13	34.13	34.13	34.13
Fish oil	0.00	1.00	2.00	3.00	4.00	5.00
Poultry offal oil	5.00	4.00	3.00	2.00	1.00	0.00
Dical. phosphate	1.88	1.88	1.88	1.88	1.88	1.88
Oyster shells	1.29	1.29	1.29	1.29	1.29	1.29
DL-methionine	0.06	0.06	0.06	0.06	0.06	0.06
L-lysine	0.16	0.16	0.16	0.16	0.16	0.16
Common salt	0.34	0.34	0.34	0.34	0.34	0.34
Coccidiostate	0.01	0.01	0.01	0.01	0.01	0.01
Mineral premix[1]	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[1]	0.25	0.25	0.25	0.25	0.25	0.25
Calculated nutrient content						
ME (Kcal kg^{-1})	3120.00	3120.00	3120.00	3120.00	3120.00	3120.00
Crude protein (%)	20.00	20.00	20.00	20.00	20.00	20.00
Calcium (%)	1.00	1.00	1.00	1.00	1.00	1.00
Available (P%)	0.45	0.45	0.45	0.45	0.45	0.45
Sodium (%)	0.16	0.16	0.16	0.16	0.16	0.16
Lysine (%)	1.25	1.25	1.25	1.25	1.25	1.25
Met + Cys (%)	0.72	0.72	0.72	0.72	0.72	0.72

[1]Supplied kg^{-1} of feed: 7,500 IU of vitamin A, 2,000 IU of vitamin D3, 30 mg of vitamin E (all-rac-α-tocopheryl acetate), 15 μg of vitamin B12, 2 mg of vitamin B6, 5 mg of vitamin K, 5 mg of vitamin B2, 1 mg of vitamin B1, 40 mg nicotinic acid, 160 μg of biotin, 12 mg of calcium pantothenate, 1 mg of folic acid, 20 mg of Fe (Ferrous sulfate), 71 mg of Mn (Manganese oxide), 100 μg of Se (Sodium selenite), 37 mg of Zn (Zinc oxide), 6 mg of Cu (Copper sulfate), 1.14 mg of I (Potassium iodide), 400 μg of Co (Cobalt sulfate) and 4 mg of butylated hydroxytoluene

Performance measurement: Performance criteria such as feed intake, weight gain, feed conversion ratio and mortality were measured weekly during the experimental period. All birds that died during the trial were weighed and feed conversion ratio was corrected for the mortality by including the weight gain of the dead birds in the body weight gain.

Sample collection: Three birds with an average live body weight of pen weight was selected and slaughtered and eviscerated in the poultry slaughterhouse. Breast fillet and thigh from each chicken were excised, singly placed in a plastic bag and stored at -20°C until fatty acid analysis and sensory evaluation tests.

Sensory evaluation: For sensory evaluation of the breast and thigh, 3 samples of either breast or thigh from each group was selected and after each sample was singly cooked with boiling water, panelists (40 people, 20 men and 20 women) scored the fishy taint of samples. The panelists evaluated the samples and awarded points on the following scale: typical poultry flavor = 1; acceptable = 2; indifferent = 3; poor = 4; fishy taint = 5.

Chemical analysis: The lipid composition was determined by means of gas chromatography system (UNICAM 4600, SB Analytical, UK) equipped with a fused silica capillary column (length 25 m, I.D. 0.53 mm). The total lipid tissue was extracted according to Folch *et al*. (1957) and was methylated with 20% boron trifluoride methanol complex in methanolic solution. The operating conditions of the gas chromatograph were as follow: the initial temperature was 75°C, increasing by 4°C min^{-1} to 148°C; from 148-158°C, the temperature was increased by 2.5°C min^{-1}; from 158-225°C the temperature was increased at the rate of 5°C min^{-1}. The temperature of the injector and the detector remained stable at 280°C. The column head pressure of the conductor gas (Helium) was 1.30 g cm^{-2}. Each FA was identified in the form of a methyl ester by comparing the retention times with the standard.

Statistical analysis: The performance and analytical data were analyzed by analysis of variance using the procedure described by SAS Institute (1999). The Duncan (1955) multiple range test was used to determine the significant differences ($p<0.05$) between the treatment means. The relationship between dietary fish oil (%) and fatty acid component was tested with simple regression analysis.

RESULTS AND DISCUSSION

The effect of fish oil replacement for animal fat in grower diet on feed intake, body weight gain and feed conversion ratio of broiler chickens are shown in Table 2. The performance of chickens fed isocaloric diets with different proportions of fish oil or animal fat were not significantly different ($p>0.05$). Alparslan and Ozdogan (2006) reported that BWG and FCR for chickens fed diets with different level of fish oil were similar, which are in

Table 2: Production performance (28-42 days), carcass traits and sensory scores of chicken meat affected by dietary fish oil

	Dietary fish oil (%)						
Variables	0	1	2	3	4	5	SEM
Production performance							
FI (g/b/day)	146.200	151.300	160.100	153.900	159.700	154.700	6.25
BWG (g/b/day)	65.200	66.600	64.500	67.300	63.100	63.400	1.74
FCR (g:g)	2.242	2.271	2.482	2.286	2.530	2.440	0.04
Mortality (%)	2.840	3.140	2.990	1.820	2.660	3.660	0.02
Carcass traits (%)							
Carcass yield[1]	66.300	67.500	67.000	67.10	68.000	66.700	1.45
Breast[2]	32.000	33.200	32.000	32.90	31.900	33.000	1.11
Thigh[2]	36.200	35.700	36.600	35.20	36.300	35.700	1.63
Abdominal fat[1]	1.880	1.760	1.830	1.92	1.85	2.010	0.08
Sensory scores							
Thigh[3]	1.0^{d}	1.27^{d}	1.25^{d}	2.32^{c}	3.25^{b}	4.02^{a}	p<0.05
Breast	1.1^{d}	1.17^{d}	1.25^{d}	2.25^{c}	3.87^{b}	4.25^{a}	p<0.05

^{a,b}: Values in the same row and variable with no common superscript differ significantly (p<0.05), [1]: As a percent of live weight; [2]: As a percent of carcass weight; [3]: Flavor scores using a 5 point scale: Typical poultry flavor = 1, acceptable = 2, indifferent = 3, poor = 4, very poor = 5

Table 3: Fatty acid composition of thigh and breast meat (mg g^{-1}) of chickens fed diets contained various level of fish oil (%)

	Dietary fish oil (%)						
Fatty acids	0	1	2	3	4	5	SEM
Thigh meat							
C18:0	1.563	1.074	2.056	1.505	2.309	1.492	0.422
C18:1	9.015	9.958	12.180	9.403	8.844	7.635	3.202
C18:2	5.427	6.203	6.143	4.607	4.203	3.273	0.089
C18:3	0.353	0.135	0.425	0.325	0.437	0.337	0.115
C20:4	0.214	0.235	0.237	0.181	0.192	0.220	0.033
C20:5	0.028^{b}	0.051^{b}	0.086^{ab}	0.165^{ab}	0.232^{a}	0.164^{ab}	0.058
C22:6	0.085^{c}	0.160^{bc}	0.270^{bc}	0.380^{ab}	0.531^{a}	0.578^{a}	0.083
Breast meat							
C18:0	0.428	0.482	0.641	0.351	0.562	0.609	0.092
C18:1	0.930^{c}	1.555^{abc}	1.901^{abc}	1.254^{bc}	2.151^{ab}	2.545^{a}	0.307
C18:2	0.544^{b}	0.868^{ab}	0.987^{ab}	0.672^{ab}	0.995^{ab}	1.113^{a}	0.163
C18:3	0.019^{b}	0.043^{ab}	0.174^{a}	0.032^{ab}	0.067^{ab}	0.065^{ab}	0.001
C20:4	0.135	0.185	0.145	0.110	0.133	0.121	0.022
C20:5	0.014^{b}	0.042^{b}	0.041^{b}	0.039^{b}	0.090^{a}	0.083^{a}	0.016
C22:6	0.046^{c}	0.145^{bc}	0.166^{bc}	0.245^{ab}	0.338^{a}	0.290^{a}	0.042

^{a,b,c}Values in the same row and variable with no common superscript differ significantly (p<0.05)

agreement with our results. The carcass yield as a percent of live weight and breast, thigh and abdominal fat as a percent of carcass weight were not significantly (p>0.05) different among treatments (Table 2). The carcass yield ranged from 66.3-68% of live weight, whereas means of breast and thigh as a percent of carcass weight were about 32 and 36, respectively. It is expected that the isocaloric diets containing 5% fat or fish oil or combination of the 2 does not affect birds performance, carcass or carcass cuts and live weight when fed during 28-42 day of age. Lopez *et al*. (2001) reported similar results when fed diets with added fish oil during 1-38 days of age. Sensory evaluation scores of thigh and breast fillet obtained from birds fed diets contained different levels of fish oil is shown in Table 2. The results revealed that the panelists did not identify the fishy smell in cooked thigh or breast fillet of birds fed diets contained 0, 1 or 2% fish oil, whereas fishy smell of meat was realized when birds diet, contained 3% or more fish oil. Our results for sensory evaluation is in agreement with other reports (Hargis and Van Elswyk, 1993; Bou *et al*., 2004). Fatty acid composition of thigh and breast fillet of birds fed diets with 5% fat or fish oil or different combination of these 2 energy sources is shown in Table 3. The results revealed that the main omega-3 Polyunsaturated Fatty Acids (PUFAs) content such as Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) increased (p<0.05) with increasing level of fish oil in diets. The precursors of the n-3 families is Linolenic Acid (LNA), which significantly (p<0.05) increased in breast, but not in thigh muscle, when level of fish oil increased in diet. The n-3 long chain Fatty Acids (PUFA) in thigh and breast linearly increased (p<0.05) with increase of fish oil in the broiler diets (Fig. 1-4). However, the meat from the birds fed diets with 0-2% fish oil may be consumed without hesitations. Since, the panelist did not identify the fishy smell of thigh or breast meat. Thus, feeding diets with 2% fish oil was shown to have the highest level of EPA and DHA concentration that may be consumed by consumers. The concentration of DHA in breast and thigh meat

Table 4: R^2 Coefficient and related equation between dietary fish oil usage and concentration of DHA and EPA in thigh and breast meat of chickens

Meat type	Fatty acids	R^2	Equation
Thigh meat	DHA	0.724	Y[1] = 0.109X[2]+0.047
	EPA	0.713	Y = 0.053X+0.007
Breast meat	DHA	0.713	Y = 0.075X+0.040
	EPA	0.593	Y = 0.02X+0.008

[1]Y = The amount of fatty acid in meat, [2]X = Dietary fish oil

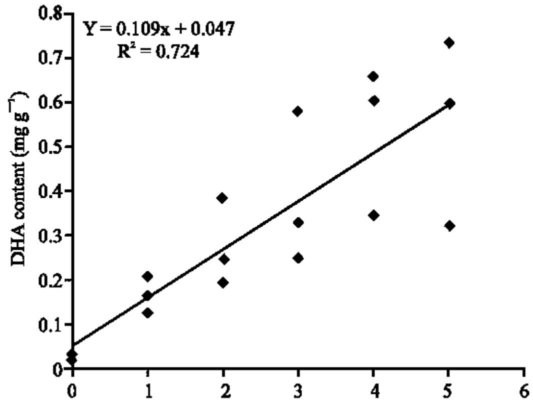

Fig. 1: Relationship between dietary fish oil and DHA content of thigh meat in chickens

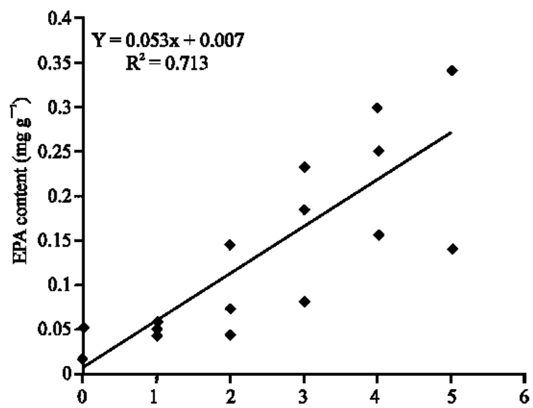

Fig. 2: Relationship between dietary fish oil and EPA content of thigh meat in chickens

increased from 0.046 and 0.086 mg g^{-1} to 0.166 and 0.27 mg g^{-1}, respectively, when dietary fish oil increased from 0-2%. Other fatty acids of thigh and breast meat of chickens fed diets with 0-2% fish oil were not significantly ($p>0.05$) different (Table 4). There are many reports that revealed the effect of dietary LC-PUFA supplied as fish oil or fish meal on the fatty acid composition of the whole carcass (Phetteplace and Watkins, 1990; Lopez-Ferrer *et al.*, 1999., Bou *et al.*, 2004). The enrichment of human diet with long chain n-3 PUFA has beneficial effects on health and resistance to various inflammatory diseases. Our study as well as others clearly

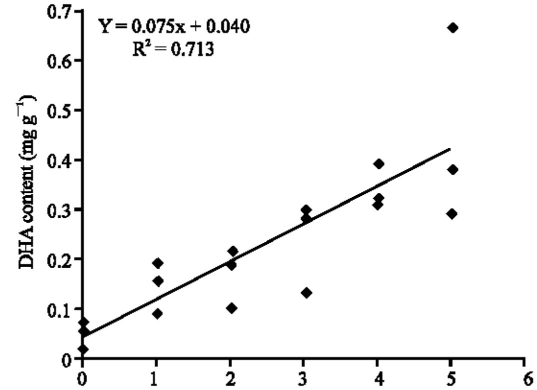

Fig. 3: Relationship between dietary fish oil and DHA content of breast meat in chickens

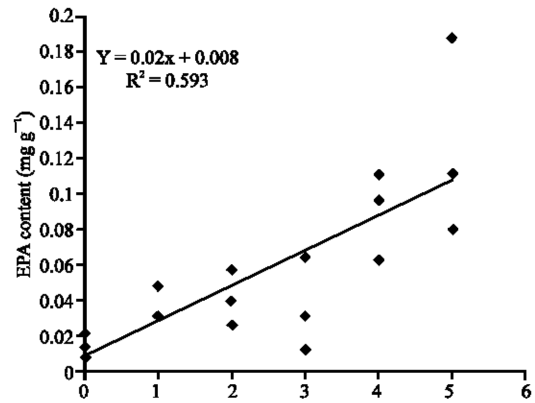

Fig. 4: Relationship between dietary fish oil and EPA content of breast meat in chickens

established that n-3 PUFA-rich diets fed to birds for 1 or 2 weeks can increase the deposition of these fatty acids in chicken meat. Dietary chicken fish oil imposed a significant linear effect on EPA in breast and thigh with R^2 of 0.59 and 0.71, respectively (Table 4). Whereas, the correlation between dietary fish oil and DHA in chicken breast and thigh resulted with R^2 of 0.71 and 0.72, respectively. It is shown that the PUFA contents of chicken cuts are deposited directly from dietary oil and to a lesser extent from de-novo synthesis through elongation and desaturation from the other carbon containing compounds. The high regression response resulted in this experiment is close to previous results (Lopez-Ferrer *et al.*, 1999, 2001).

CONCLUSION

The replacement of dietary fat with fish oil, does not have any negative effect on broiler chicken performance. The meat from chickens fed diet supplemented with >2%

fish oil is not acceptable to consumers. The amount of DHA in thigh or breast fillet may be increased more than 3X when chickens fed diet with 2% fish oil.

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