African Journal of Biotechnology Vol. 10(51), pp. 10484-10490, 7 September, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.1133
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Comparison of yolk fatty acid content, blood and egg cholesterol of hens fed diets containing palm olein oil and kilka fish oil

S. J. Hosseini-Vashan[1], N. Afzali[2]*, A. Golian[1], A. Allahressani[3], M. A. Nasseri[3] and M. Mallakeneh[4]

[1]Center of Excellence, Department of Animal Science, Faculty of Agriculture, Ferdowsi University of Mashhad, P.O. Box 91775-1163, Mashhad, I. R. Iran.
[2]Department of Animal Science, Faculty of Agriculture, Birjand University, Birjand, I. R. Iran.
[3]Department of Chemistry, Faculty of Sciences, Birjand University, Birjand, I.R. Iran.
[4]Department of Medical Biochemistry, Faculty of Medicine, Birjand University of Medical Sciences, Birjand, I. R. Iran.

Accepted 21 July, 2011

The purpose of this study was to compare the effects of dietary palm olein oil (POO) and Kilka fish oil (KFO) on yolk fatty acid content, ratio of fatty acids (FAs), antibody titre, and blood and yolk cholesterol of laying hens. One hundred White Hy-Line 26-wk-old (W-36) hens were allotted to 6 dietary treatments containing 0, 1.5, 3 and 4.5% POO or 2 and 4% KFO. The FAs and cholesterol content of yolk were measured at the end of three consecutive days of each period. Results reveal that the oleic acid increased and palmitic acid decreased (P<0.05) when hens were fed diets containing POO. The KFO diets reduced the blood cholesterol, yolk linoleic acid and yolk ω-6 FA (P<0.05), whereas the blood cholesterol increased by the supplementation of POO to dietary treatments. The yolk long chain polyunsaturated ω-3 FAs [Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)] increased as KFO was increased in diets (P<0.001). The diets supplementation of KFO and POO thus, showed a decrease and an increase in the ratio of ω-6/ ω-3 FAs (P<0.05), respectively. It is concluded that supplementation of KFO to the dietary treatment may improve deposition of ω-3 FAs; however, the POO supplementation may improve deposition of ω -9 FAs without alteration of yolk cholesterol.

Key words: Palm olein oil (POO), Kilka fish oil (KFO), hens, egg omega-9 and omega-3 fatty acid.

INTRODUCTION

Nutritional quality of fat in food products may be enhanced by taking into account the cholesterol concentrations, saturated fatty acids (SFAs), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acid (PUFA) (Milinsk et al., 2003). Humans consume poultry "meat and egg" in large amounts, hence, it is important to enrich the poultry products. Palm oils, having the highest percentage of production in the entire world, has a high concentration of SFAs specifically palmitic acid, and low concentration of other fatty acids [monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA)]. Palm olein oil (POO), having high content of oleic acid and MUFA, is produced from palm oil. The MUFA is necessary for the myelinization of the nervous system in growing children (Uauy and Olivares, 2007), lipolysis (Soriguer et al., 2003), and reduction of mammary tumors and bactericidal action (Schlesinger and Uauy, 1991). The POO was added to hen diets to decrease blood and

*Corresponding author. E-mail: afzali.nazar@yahoo.com.

Abbreviations: POO, Palm olein oil; **KFO,** kilka fish oil; **FAs,** fatty acids; **EPA,** eicosapentaenoic acid; **DHA,** docosahexenoic acid.

egg cholesterol (Hodzic et al., 2008). Punita and Chaturvedi (2000) reported that egg cholesterol reduced, as the red palm oil was added to the hen diet.

On the other hand, fish oil is the best source of long chain omega-3 fatty acids (LCUFAs) such as eicosapentaenoate (EPA), docosapentaenoate (DPA) and docosahexaenoate (DHA). Feeding fish oil as higher content of linolenic acid (LNA) enhances apparent elongase and desaturase activity on the ω -3 PUFA pathways, whereas plant diets including higher concentration of linoleic acid (LA) enriches apparent activity of elongase and desaturase on the ω -6 PUFA pathways. The β-oxidation of LNA in fish oil diet was higher than other diets containing palm oil and linseed, whereas bioconversion of LA in fish oil was lower than palm oil groups (Poureslami et al., 2010). The LCUFAs have a major role in reducing the blood viscosity, pressure, platelet aggregation, and cardiac arrhythmia; therefore, it reduces the chance of some human disease occurrence such as, cardiovascular, coronary heart and inflammatory problems (Farrell, 1994; Connor, 2000). Dietary omega-3 fatty acids may delay the loss of immunological functions (Fernnades, 1995), and is required for normal fetal brain and visual development (Neuringer et al., 1988). It may also provide an inhibitory effect on prostate growth and breast cancer (Okuyama et al., 1997). In birds, the omega-3 fatty acids reduce the occurrence of sudden death syndrome (SDS), and coccidiosis (Leavander et al., 1992). However, these fatty acids may affect egg production, growth rate, immune system and osteogenesis in poultry (Leavander et al., 1992; Allen and Danfort, 1998). New reports suggested an appropriate ratio of omega-6: omega-3 for human health. It is worth mentioning that most researchers proposed the ratio of smaller than 5 or 4, but the most appropriate is 1. Nowadays, this ratio in western diets is about fifteen (Shimizu et al., 2001; Simopolous, 2002).

The rationale for this study was to compare the beneficial effects of dietary palm olein oil or Kilka fish oil to increase the ω-3 fatty acids and decrease the ratio of omega-6/omega-3 in egg. In addition, the relationship between the fatty acids precursors in hen diet and the content of the different ω-3 and ω-9 PUFA families were studied in edible eggs.

MATERIALS AND METHODS

A total of one hundred and forty-four 26-week-old white Hy-Line "W-36" laying hens were randomly allotted to six dietary treatments including control, 1.5, 3, 4.5% palm olein oil (POO) or 2 and 4% kilka fish oil (KFO). Each dietary treatment was fed to three groups of 8 birds each. The hen cages were located in an environmentally controlled commercial house. Diets were formulated to have similar nutrients and metabolizable energy (NRC, 1994), with/without different concentrations of POO or KFO. Feed and water were supplied *ad libitum* (Table 1). The house temperature was maintained at 20 ± 2°C with 16:8 h light:dark cycle. The trial started after a pre-experimental period of two weeks for adjustment to the test diets and continued for three periods of four weeks each.

Egg production and egg quality measurements

Egg production, feed consumption, feed conversion ratio (FCR), egg weight, and egg mass of each replicate bird were recorded weekly. Egg quality parameters such as; haugh unit score, yolk color index (as measured by Roche yolk color fan), yolk index, egg shape, and shell weight were measured for three randomly collected eggs from each experimental unit in the last three consecutive days of every period. Birds of each group were weighed at the beginning and termination of experiment.

Egg and blood analyses

Egg cholesterol was measured in three yolk samples collected from each replicate hens after being stored in freezer (-20°C). To measure the egg cholesterol, lipids were briefly saponified by ethanolic 0.5 N KOH and N-hexane, after lipids extraction. The extracted cholesterol was placed on spectrophotometer, using Parsazmon kit to measure the yolk cholesterol content. At the end of experiment, the blood cholesterol was determined by withdrawing 3 ml of blood into a non-heparinized tube from one hen in every group through the brachial vein. Bloods were centrifuged and serums were collected after 8 to 10 h and stored in -20°C freezer for subsequent analysis. Individual serum samples were analyzed for antibody responses against Newcastle disease (ND). The ND titer was determined by haemagglutination inhibition (HI) technique.

Fatty acid analysis

Yolks from collected eggs were separated and stored at -20°C for subsequent fatty acid analysis. Total lipid was extracted from egg yolk according to the method of Folch (Folch et al., 1957) and fatty acids were determined. Briefly, 0.5 g of yolk was weighed into a test tube with 20 ml of hexane: methanol mixture (2:1, v:v), and methylated with 15% boronitrifluoride methanol complex (BF3) in methanolic solution (Morrison and Smith, 1964). Fatty acid methyl esters (FAMEs) were separated and quantified by gas chromatography using Shimadzu GC-16A chromatograph equipped with a CP-Sil 88 capillary column (Fused silica capillary column; length, 100 m; I.D., 0.25 mm;), film, and a flame ionization detector (FID). The operating conditions of gas chromatograph were as follow: the oven temperature was held at 130°C for 5 min, increased to 217°C at a rate of 3°C/min, then increased with rate of 4°C/min to 230°C and held at this temperature for 25 min. The temperature of the injection and detector was 280 and 300°C, respectively. The column head pressure of the conductor gas (helium) was 2.20 g/cm^2. Fatty acid peaks were identified as compared with retention times of FAME standards (Sigma Quimica, S.A, Apdo. Correos 161, 28100 Alcobendas, Spain). Quantification was made by an internal standard (C19:0) added to the initial sample.

Statistical analysis

All data were analyzed as a completely randomized design (repeated measurement) using mixed models procedure of SAS software 6.04 (SAS Institute Inc., 1991). The general linear models (GLM) procedure was used to analyze the data of blood parameters and body weight. The statistical differences between means were analyzed by repeated measures and Tukey's test ($P<0.05$).

Table 1. Composition of diets containing different levels of palm olein oil (POO) and kilka fish oil (KFO).

Ingredient (%)	Control	POO in diet (%)			KFO in diet (%)	
		1.5	3	4.5	2	4
Corn	66.46	51.32	44.87	42.06	46.39	42.88
Soybean meal	20.10	19.45	19.79	20.82	19.29	20.72
Wheat	1.00	15.57	20.00	20.00	20.00	20.00
POO	0.00	1.50	3.00	4.50	0.00	0.00
KFO	0.00	0.00	0.00	0.00	2.00	4.00
Limestone	8.66	8.50	8.58	8.79	8.55	8.65
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00
DCP	0.73	0.70	0.74	0.78	0.76	0.76
Salt	0.38	0.31	0.35	0.36	0.34	0.34
Mineral premix2	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix1	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.07	0.08	0.08	0.08	0.07	0.08
Methionine	0.10	0.07	0.09	0.11	0.10	0.07
Calculated analyses						
Crude protein	16.10	16.12	16.20	16.36	16.10	16.34
ME (MJ/kg)	11.80	11.80	11.97	12.13	11.80	12.05
Phosphorous	0.44	0.45	0.45	0.48	0.44	0.47
Calcium	3.67	3.68	3.69	3.73	3.68	3.70
Lysine	0.86	0.86	0.87	0.94	0.86	0.84
Meth + Cys	0.69	0.69	0.68	0.72	0.68	0.67

Supplied (mg/per kilogram diet): retinol 2.64, cholecalciferol 0.062, alpha-tocopherol 25.3, thiamin 1.477, riboflavin 4, niacin 17.84, pyridoxine 2.462, cyanocobalamin 0.02, menadione 2.2, folic acid 0.48, biotin 0.15, manganese oxide 74.4, ferric oxide 75, zinc oxide 64.75, copper sulfate 6, Selenium 0.2, choline chloride 200.

RESULTS

Production parameters such as egg production, egg weight, egg mass, feed intake and feed conversion ratio were not affected by dietary palm olein oil and kilka fish oil (data not shown) and the mean values were 90.26%, 57.09 g/egg, 51.52 g/bird/day, 94.41 g/bird/day and 1.83 g:g, respectively. The dietary treatments did not alter the egg quality measurements such as haugh unit, egg shape index (egg transverse span/egg long span), yolk shape index (yolk height/yolk diameter) and yolk color index (data not shown). The body weight gain (BWG) increased with an increment of POO or KFO in the laying hen dietary treatments (Table 3) and the highest BWG was found in birds fed diets containing 4.5% POO (170 g) or 4% KFO (168 g) ($P<0.05$).

The cholesterol content of blood, yolk and egg and serum antibody titer against ND of control and hens fed diets containing POO or KFO is shown in Table 3. Dietary POO did not significantly affect yolk and egg cholesterol content, whereas KFO significantly decreased the egg cholesterol. The POO increased blood cholesterol, whereas the KFO decreased it. The antibody response to ND vaccines was not changed by the type and content of dietary oils. The average antibody titer against ND was 8.5.

Fatty acid composition of control diet and diets containing palm olein oil and kilka fish oil are shown in Table 2. The saturated fatty acids in yolk were significantly ($P>0.05$) affected when hens were fed diets containing up to 4.5% of POO or 4% KFO. The effects of feeding palm olein oil and kilka fish oil on fatty acid composition of egg yolk is shown in Table 4. The meristic and stearic acids in egg yolk content numerically reduced with an increase in POO or KFO in diets ($P>0.05$). Palmitic acid and sum of SFAs in yolk content of hens fed with higher levels of POO significantly decreased. The minimum concentrations of SFAs and palmitic acid found in egg yolk of hens fed 4.5% POO were 38.81 and 29.76% of total fatty acids, respectively (Table 4). The palmitoleic acid (an index of ω-7 FA family) did not significantly ($P>0.05$) differ when birds were fed control or diets containing up to 4.5% POO or 4% KFO (Table 4). Dietary POO increased ($P<0.05$) the concentration of oleic acid (ω-9 FA) and monounsaturated FAs in egg yolks, while dietary KFO did not change yolk oleic acid

Table 2. Fatty acid compositions of control and diets containing different levels of palm olein oil (POO) and kilka fish oil (KFO).

Fatty acid (%)	Control	POO in diet (%)			KFO in diet (%)	
		1.5	3	4.5	2	4
$C_{14:0}$	1.14	1.39	1.47	1.37	2.09	2.14
$C_{16:0}$	30.28	27.36	24.49	21.81	33.07	33.11
$C_{16:1}$ ω -7	3.59	2.14	2.42	2.40	2.24	2.27
$C_{18:0}$	8.49	8.19	7.88	7.72	10.49	10.98
$C_{18:1}$ ω -9	34.72	43.15	48.18	52.41	28.29	26.41
$C_{18:2}$ ω -6	20.21	16.23	14.31	13.18	17.78	16.65
$C_{18:3}$ ω -3	0.12	0.07	0.03	0.02	0.09	0.11
$C_{20:4}$ ω 6	1.39	1.45	1.19	1.08	1.54	1.97
$C_{20:5}$ ω -3	0.05	0.01	0.02	0.01	3.43	4.58
$C_{22:6}$ ω -3	0.01	0.01	0.01	0.01	0.98	1.78

Table 3. Comparison effects of dietary palm olein oil (POO) and kilka fish oil (KFO) on body weight gain, blood and egg cholesterol and serum antibody titers.

Treatment	Body weight gain (g)	Egg cholesterol (mg/egg)	Yolk cholesterol (mg/g)	Blood cholesterol (mg/dl)	ND titer
Control	90.0^{c}	196.02^{a}	13.08	143.00^{b}	8.67
1.5% POO	98.0^{c}	198.03^{a}	13.20	155.67^{ab}	8.33
3% POO	118.0^{b}	201.75^{a}	13.45	161.00^{a}	8.33
4.5% POO	170.0^{a}	204.92^{a}	13.66	162.33^{a}	8.67
2% KFO	124^{b}	183.03^{ab}	12.20	148.67^{b}	8.00
4% KFO	168^{a}	177.02^{b}	11.80	131.67^{c}	8.00
N	6	9	9	3	3
Pooled SEM	49.23	83.25	0.51	41.56	0.67
P value (treatment)	<.0001	0.018	0.046	0.0005	0.845
Root MSE	7.016	9.12	0.714	6.44	0.819
Probability					
Oil	<.0001	0.61	0.62	0.042	0.458
POO	<.0001	0.38	0.48	0.002	0.693
KFO	<.0001	0.030	0.052	0.546	0.275

^{a,b,c}, Means in column no common superscript differ significantly (P<0.05).

content. KFO decreased yolk linoleic acid (LA); however, POO did not affect yolk LA. Arachidonic acid (AA) and LNA content of yolk was not statistically (P>0.05) altered in hens fed diets containing POO or KFO. The long chain fatty acids (DHA, and EPA) content of egg yolk were not influenced by dietary POO. The KFO increased yolk DHA and EPA. In addition, the highest concentration of yolk unsaturated fatty acid (UFAs) was observed when hens were fed high level of POO diet. Thus the lowest ratio of UFAs/SFAs was observed in those birds (P<0.05). The ratio of ω-6/ ω-3 fatty acids decreased when hens were fed diets containing KFO, although, POO increased this ratio.

DISCUSSION

Higher BWG was found in birds fed diets containing higher percentage of POO and KFO. This may be due to lower heat increment and passage rate (Leeson and Summers, 2001). Dietary POO did not significantly affect yolk and egg cholesterol content, whereas KFO significantly decreased the egg cholesterol. The KFO and higher concentration of long chain polyunsaturated fatty acids may affect cholesterol metabolism and tissues and egg deposition. These results are in accordance with the reports of van-Elsweyk et al. (1992) and Mori et al. (1999), although, other researchers reported the egg or

Table 4. Comparison of egg yolk fatty acid profile (% of total fatty acid) in hens fed diet contained palm olein oil (POO) and kilka fish oil (KFO).

Parameter	C14:0	C16:0	C16:1n-7	C18:0	C18:1n-9	C18:2n-6	C18:3n-3	C20:4n-6	C20:5n-3	C22:6n-3
Control	0.858	34.97^{a}	2.771	9.310	39.43^{c}	10.67^{a}	0.499	1.29	0.158^{c}	0.032^{c}
1.5% POO	0.995	33.11^{ab}	3.816	8.909	40.23^{c}	10.41^{a}	0.467	1.92	0.128^{c}	0.029^{c}
3% POO	0.776	32.09^{ab}	2.831	8.703	43.04^{b}	10.40^{a}	0.470	1.55	0.101^{c}	0.023^{c}
4.5% POO	0.772	29.76^{b}	3.023	8.281	45.86^{a}	10.30^{a}	0.466	1.42	0.089^{c}	0.030^{c}
2% KFO	0.889	33.75^{a}	3.484	9.106	40.48^{c}	8.47^{b}	0.555	1.64	0.513^{b}	1.110^{b}
4% KFO	0.963	33.12^{ab}	3.393	9.399	40.36^{c}	7.53^{b}	0.556	1.34	0.886^{a}	2.448^{a}
Pooled SEM	0.0194	3.788	0.4339	0.6227	0.607	0.628	0.0028	0.304	0.0073	0.0059
P value1	ns	0.002	ns	ns	<.0001	<.0001	ns	ns	<.0001	<.0001
Probability										
Oil2	ns	0.006	ns	ns	<.0001	0.001	ns	ns	<.0001	<.0001
Poo3	ns	0.001	ns	ns	<.0001	Ns	ns	ns	ns	ns
KFO4	ns	ns	ns	ns	ns	<.0001	ns	ns	<.0001	<.0001

Parameter	∑SFA*	∑MUFA	∑ MUFAn-9	∑PUFAn-6	∑PUFAn-3	n-6/n-3	∑ PUFA	∑UFA	∑SFA/∑ PUFA	∑SFA/ ∑ UFA	∑SFA*
Control	45.14^{a}	42.20^{c}	39.43^{c}	11.96^{a}	0.689^{c}	17.57^{a}	12.65	54.86^{d}	3.568	0.823^{a}	45.14^{a}
1.5% POO	43.01^{ab}	44.05b^{c}	40.23^{c}	12.32^{a}	0.624^{c}	19.89^{a}	12.94	56.99^{bc}	3.323	0.755^{b}	43.01^{ab}
3% POO	41. 57^{bc}	45.87^{b}	43.04^{b}	11.95^{a}	0.595^{c}	20.32^{a}	12.55	58.42^{b}	3.313	0.712^{b}	41. 57^{bc}
4.5% POO	38.81^{c}	48.89^{a}	45.86^{a}	11.72^{a}	0.585^{c}	20.13^{a}	12.31	61.19^{a}	3.154	0.634^{c}	38.81^{c}
2% KFO	43.75^{ab}	43.96^{bc}	40.48^{c}	10.11^{b}	2.178^{b}	4.687^{b}	12.29	56.25^{cd}	3.560	0.778^{ab}	43.75^{ab}
4% KFO	43.49^{ab}	43.75^{c}	40.36^{c}	8.87^{b}	3.890^{a}	2.290^{b}	12.76	56.51^{bcd}	3.409	0.770^{ab}	43.49^{ab}
Pooled SEM	3.516	1.443	0.607	0.504	0.0211	2.522	0.527	1.365	0.1013	0.0015	3.516
P value1	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	ns	<.0001	ns	<.0001	<.0001
Probability											
Oil2	0.001	<.0001	<.0001	ns	<.0001	<.0001	ns	<.0001	ns	<.0001	0.001
Poo3	<.0001	<.0001	<.0001	ns	ns	ns	ns	<.0001	ns	<.0001	<.0001

^{a,b,c}, Means in column with no common superscript differ significantly (P<0.05). Values are mean of 6 determination/diet expressed as percentage of total fatty acid in egg yolk.*SFA: Saturated fatty acid, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acids, UFA: unsaturated fatty acid.
^{1}P Value of comparison of treatments; ^{2}P Value of oil inclusion; ^{3}P Value of level of palm olein oil (POO) inclusion; ^{4}P Value of level of kilka fish oil (KFO) inclusion.

yolk cholesterol content was not influenced by dietary omega-3 fatty acids (Caston and Leeson, 1990; Scheideler and Froning, 1996). Alteration of blood cholesterol among dietary treatments may be due to the composition of SFAs, because some of SFAs induce cholesterol synthesis. This finding is in agreement withother researchers (Mori et al., 1999; Brenes et al., 2008) observing the increase of blood cholesterol in hens fed dietswith high oleic sunflower seeds.

The cholesterol, low density lipoprotein (LDL) and very low density lipoprotein (VLDL) decreased, while high density lipoprotein (HDL) increased when birds were fed fish oil (Chashnidel et al., 2010; Navidshad et al., 2010). The antibody response to ND vaccines was not changed by the researchers did not observe any changes in antibody response to omega-3 fatty acids (Grobas et al., 2001; Milinsk et al., 2003). However, Puthpongsiriporn and Scheideler (2005) reported that low ratio of ω-6/ω-3 fatty acids reduced the ND titer and did not affect the IBD titer.

The meristic and stearic acids in egg yolk content numerically reduced with an increase in POO or KFO in diets (P>0.05). Palmitic acid and the sum of SFAs in yolk content of hens fed higher levels of POO significantly decreased. Some researchers reported that yolk SFAs in hens fed diets containing different concentrations of omega-3 fatty acids (Baucells et al., 2000; Grobas et al., 2001; Milinsk et al., 2003) and palm oil is nearly constant (Cherian et al., 1996; Kang et al., 2001). Several scientists (Jiang and Sim, 1991; Baucells et al., 2000) concluded that the capacity of laying hens to alter the yolk content of saturated FAs through dietary modification is quite limited.

Dietary POO increased (P<0.05) the concentration of oleic acid (ω-9 FA) and MUFA. Similar results were also reported by other researchers (Cherian et al., 1996; Azcona et al., 2008); however Kang et al. (2001) reported that palm oil did not alter the yolk oleic acid and MUFA. Diets containing high concentration of oleic acid resulted in higher activity of Δ-9 desaturase compared to Δ-6 desaturase (Brenner, 1974; Garg et al., 1988). LA is the largest component of ω-6 polyunsaturated fatty acids. POO did not affect yolk LA. This may be due to low concentration of LA in POO. This is in agreement with other researchers (Cherian et al., 1996; Kang et al., 2001). The KFO however decreased egg yolk LA. Bioconversion of LA in palm oil diet was higher than fish oil diet (Poureslami et al., 2010). A lower content of yolk LA was also reported in hens fed diets containing menhaden and palm oil compared to hens fed sunflower and flax oil (Cherian et al., 1996; Cherian and Sim, 1997). Therefore, changing metabolism and deposition of LA may be due to the percentage of other fatty acids in the diets. AA content of yolk was not statistically (P>0.05) altered in hens fed diets containing POO or KFO. This may be due to low concentration of ω-6 fatty acids in dietary treatments.

The dietary POO and KFO did not significantly (P>0.05) affect yolk LNA. The β-oxidation of LNA in fish oil diet was higher than other diets such as palm oil and linseed (Poureslami et al., 2010). This fatty acid is a precursor of long chain ω-3 fatty acids (docosahexaenoic acid (DHA), DPA and EPA) and plays important roles in the body function (Simopolous, 2002). The long chain Fatty acid (DHA, and EPA) content of egg yolk was not influenced by dietary POO. The KFO, however, increased yolk DHA and EPA. In addition, the highest concentration of yolk unsaturated fatty acid (UFA) was observed when hens were fed high level of POO diet. Thus, the lowest ratio of UFAs/SFAs was observed in those birds (P<0.05).There is a competition between the activity of Δ-5, Δ-6 desaturase on omega-3 FAs family and omega-6 FAs (Sargent et al., 1995). In KFO diets, higher activity of elongase and Δ-5 and Δ-6 desaturase probably affected synthesis of omega-3 fatty acids, which is related to higher yolk deposition of long chain ω-3 fatty acids. The KFO increased yolk concentrations of Σ-omega-3 fatty acids; however this was not altered in POO. The enhancement of long chain ω-3 fatty acids may improve the health of consumers due to its important roles in many body reactions.

The ratio of ω-6/ ω-3 fatty acids is also an important factor to evaluate egg enrichment, which may affect consumer health. This ratio decreased when hens fed diets contained KFO, although, POO increased this ratio. The lower ratio of ω-6/ ω-3 fatty acids in yolk of hens fed higher content of KFO could be related to higher concentration of long chain fatty acids, Σ-omega-3 fatty acids, and lower density of LA in these eggs. Currently, some researchers believe that the best ratio of ω-6/ ω-3 fatty acids in food products for human health is 1, but preparing diets with this characteristic is very difficult. Thus, scientists proposed an acceptable ratio of less than 5 (Baucells et al., 2000; Shimizu et al., 2001; Simopolous, 2002).

Conclusion

The MUFA and omega-9 fatty acids in egg yolk was elevated incrementally as inclusion of POO increased in hen diets, whereas, the omega-3 fatty acids especially long chain ω-3 polyunsaturated increased with an increment of KFO in diet. The dietary POO and KFO may also increase and decrease yolk omega-6/omega-3 fatty acids ratio, respectively. Thus, modifying the fatty acid composition of diet may alter lipid metabolism in animal.

ACKNOWLEDGEMENTS

The authors would like to specially thank the manager of Birjand Behparvar Layer Farm, the Chemistry Department

of Birjand University and the South Khorasan Governors' office for their financial support of this study.

REFERENCES

Allen PC, Danfort HD (1998). Effects of dietary supplementation with ω-3 fatty acid ethyl esters on coccidiosis in chickens. Poult. Sci., 75: 179-185.

Azcona JO, Garcia PT, Cossu ME, Iglesias BF, Picallo A, Perez C, Gallinger CI, Schang MJ, Canet ZE (2008). Meat quality of Argentinean "Camperos" chicken enhanced in omega-3 and omega-9 fatty acids. Meat Sci., 79: 437–443.

Baucells MD, Crespo N, Barroeta AC, Lopez-Ferrer S, Grashornt. MA (2000). Incorporation of different polyun-saturated fatty acid into eggs. Poult. Sci. 79: 51-59.

Brenes A, Centeno C, Viveros A, Arija I (2008). Effect of Enzyme Addition on the Nutritive Value of High Oleic Acid Sunflower Seeds in Chicken Diets. Poult. Sci., 87: 2300-2310.

Brenner RR (1974). The oxidative desaturation of unsaturated fatty acids in animals. Mol. Cell Biochem., 3: 41-52.

Caston L, Leeson S (1990). Dietary flax and egg composition. Poult. Sci., 69: 1617-1620.

Chashnidel Y, Moravej H, Towhidi A, Asadi F, Zeinodini S (2010). Influence of different levels of n-3 supplemented (fish oil) diet on performance, carcass quality and fat status in broilers. Afr. J. Biotechnol., 9(5): 687-691.

Cherian G, Sim JS (1997). Egg yolk polyunsaturated fatty acids and vitamin E content alters the tocopherol status of hatched chicks. Poult. Sci., 76: 1753-1759.

Cherian G, Wolfe FH, Sim JS (1996). Dietary oils with added tocopherols: Effects on egg or tissue tocopherols, fatty acids, and oxidative stability. Poult. Sci., 75: 423–431.

Connor EW (2000). Importance f n-3 fatty acid in health and disease. Am. J. Clin. Nutr., 7(suppel): 171-175.

Farrell DJ (1994). The fortification of hen's eggs with omega-3 long chain fatty aid and their effects in humen. In egg users and processing technologies new developments. Eds J. S. Sim and S. Nakai. CABI, UK.pp. 386-401.

Fernnades G (1995). Effects of calorie restriction and omega-3 fatty acids on autoimmunity and aging. Nutr. Rev. 53: S72-79.

Folch J, Less M, Sloane-Stanely GH (1957). A simple method for the isolation and purification of total fatty acids from animal tissues. J. Biol. Chem., 226: 497-507.

Garg ML, Sebokova E, Wierzbicki A, Thomson A, Clandinin MT (1988). Different effects of dietary linoleic and α-linolenic acid on lipid metabolism of rat tissues. Lipid, 23: 847-851.

Grobas S, Mendez J, Lazar L, De Blas C, Mateos GG (2001). Influence of source and percentage of fat added to diet on performances and fatty acid composition of egg yolks of two strains of laying hens. Poult. Sci., 80: 1171–1179.

Hodzic A, Hamamdzic M, Gagic A, Mihaljevic M, Vegara M, Krnic J, Juhas EP (2008). The influence of dietary palm olein, fish oil and lard on the egg yolk and plasma lipid composition, and performances of laying hens. J. Vet. Sci., 11(1): 1-7

Jiang Z, Sim JS (1991). Consumption of n-3 polyunsaturated fatty acid-enriched eggs and changes in plasma lipids of human subjects. Nutrition, 9: 513-518.

Kang KR, Cherian G, Sim JS (2001). Dietary palm oil alters the lipid stability of polyunsaturated fatty acid modified poultry products. Poult. Sci., 80: 228–234.

Leavander OA, Ager AL, Morris VC, Fontela R, May RG (1992). Menhaden oil protects against malaria in mice fed ground chow. Fed. Amer. Soc. Exper. Biol., 6: p. 1212.

Leeson S, Summers D (2001). Scott's nutrition of the chicken. 4th edition, Nottingham University Press.

Milinsk MC, Murakami AE, Gomes STM, Matsushita M, De-Souza NE (2003). Fatty acid profile of egg yolk lipids from hens fed diets rich in n-3 fatty acids. Food Chem. 83: 287–292.

Mori AV, Mendonca CX, Santos COF (1999). Effect of dietary lipid lowering drug upon plasma lipids and egg yolk cholesterol levels of laying hens. J. Agric. Food Sci., 47: 4731- 4735.

Morrison WR, Smith ML (1964). Preparation of fatty acid methyl esters and dimethylacetates from lipid with boron trifluoride methanol. J. Lipid Res., 5: 600-608.

Navidshad B, Deldar H, Pourrahimi GH (2010). Correlation between serum lipoproteins and abdominal fat pad in broiler chickens. Afr. J. Biotechnol., 9(35): 5779-5783

National Reserch Counicle (1994). Nutrient Requirements of Poultry. 9th Rev. ed. National Academy Press, Washington, Dc.

Neuringer M, Anderson GJ, Connor WE (1988). The essentiality of n-3 fatty acids for the development and function of the retina and brain. Annual Rev. Nutr., 8: 517-541.

Okuyama H, Kobayashi T, Watanaba S (1997). Dietary fatty acids- The n-6/n-3 balance and chronic elderly diseases excess linoleic acid and relative n-3 deficiency syndrome seen in Japan. Lipid Res., 35: 409-457.

Poureslami R, Raes K, Turchini GM, Huyghebaert G, De-Smet S (2010). Effect of diet, sex and age on fatty acid metabolism in broiler chickens: n-3 and n-6 PUFA. Br. J. Nutr., 1-9.

Punita A, Chaturvedi A (2000). Effect of feeding crude red palm oil (Elaeis guineensis) and grain amaranth (Amaranthus paniculatus) to hens on total lipids, cholesterol, PUFA levels and acceptability of eggs. Plant Foods Hum. Nutr., 55: 147–157.

Puthpongsiriporn U, Scheideler SE (2005). Effects of dietary ratio of linoleic to linolenic acid on performance, antibody production, and in vitro lymphocyte proliferation in two strains of leghorn pullet chicks. Poult. Sci., 84: 846–857.

Sargent JR, Bell JG, Bell MV, Hendersson RJ, Tocher DR (1995). Requirement criteria for essential fatty acids. J. Appl. Ichthy., 11: 183-198.

SAS Institute (1991). SAS R User's Guide: Statistics. Version 6.04 Edition. SAS Institute Inc. Cary, NC.

Scheideler SE, Froning GW (1996). The combined influence of dietary flaxseed variety, level, form, and storage conditions on egg production and composition among vitamin E-supplemented hens. Poult. Sci. 75: 1221-1226.

Schlesinger L, Uauy R (1991). Nutrition and neonatal immune function. Sem. Perinat. 15(6): 469–477.

Shimizu YK, Ise-Arai S, Shimasaki H (2001). Dietary fish oil for hens affects the fatty acid composition of egg yolk phospholipids and gives a valuable food with an ideal balance of n-6 and n-3 essential fatty acids for human nutrition. J. Oleo Sci. 50: 797–803.

Simopoulos AP (2002). The importance of the ratio of omega-6/omaga-3 essential fatty acids. Biomed Pharmacother., 56: 253-264.

Soriguer F, Moreno F, Rojo-Martinez G, Garcia-Fuentes E, Tinahones F, Gomez-Zumaquero JM, Cuesta-Munoz AL, Cardona F, Morcillo S (2003). Monounsaturated ω-9 fatty acids and adipocyte lipolysis in rats. Br. J. Nutr., 90: 1015-1022.

Uauy DR, Olivares S (2007). Importancia de las grasas y aceites para el crecimiento y desarrollo de los ninos. FAO http://www.fao.org/DOCREP/ T4660T/ T4660T05 .htm.

van-Elswyk ME, Sams AR, Hargis PS (1992). Composition, functionaly, and sensory evaluation of eggs from hens fed dietary menhaden oil. J. Food Sci., 57(2): 342-349.