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Full Length Research Paper

A study on correlation coefficients between fatty acids in the meat of chickens fed fatty acids (PUFAs) rich diets

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An experiment was conducted to study variations in the concentrations of fatty acids and the ratio between n-6 and n-3 fatty acid concentrations in chicken meat fed diet containing fish oil (n-3 rich), soybean oil (n-6 rich) or palm oil. The main fatty acids in broiler breast and thigh tissues were oleic acid, palmitic acid, linoleic acid and stearic acid. The birds fed the experimental diets containing 7% fish oil had a much lower and more favorable ratio between total n-6 and n-3 fatty acids; being about 0.6:1 and 0.9:1, and the ratio between amino acid (AA) and eicosapentaenoic acid (EPA) was about 0.06:1 and 0.07:1 in breast and thigh muscles, respectively. The broiler meat in the present study could be a healthful element of the human diet. The concentration of the dominant fatty acid in broiler breast muscle, oleic acid was strongly and positively correlated to those of C12:0, C14:0, C16:0 and C16:1. In thigh tissue, these correlation coefficients were highly stronger as compared to the breast muscle. EPA and docosahexaenoic acid (DHA) correlates negatively to the C20:0, C22:0 and C24:0 fatty acids. This suggests that these long chain n-3 polyunsaturated fatty acids (PUFAs) might inhibit elongation.

Key words: Polyunsaturated fatty acids (PUFAs), meat fatty acids, correlation coefficients, broiler chickens.

INTRODUCTION

Chicken meat is usually recommended as a healthy type of meat and it is popular all over the world (Norwegian Dietary Information, 2004). Chicken meat is protein-rich and has low fat; and its fatty acid profile is highly dependent on the dietary supply. A typical commercial chicken feed is rich in grains having a high ratio between n-6 and n-3 fatty acids. This ratio is extremely dissimilar to the natural feeds rich in green leaves with high n-3 fatty acids and specially alpha-linolenic acid (ALA).

There is a competition between n-6 and n-3 fatty acids for binding to several enzymes such as elongases, desaturases, cyclooxygenases and lipoxygenases and also to incorporate into membrane lipids (Insel et al., 2004; Schmitz and Ecker, 2008). The long-chain n-3 fatty acids have a specific protective role and it is important that the intake of these fatty acids should not be too low (Leaf et al., 2008; Brenna and Diau, 2007). In the modern human ratios, the n-6 ton-3 fatty acids ratio, especially the AA/(EPA + DHA) ratio, is high. A lower ratio dietary n-6 to n-3 fatty acids ratio is more favorable because it may help to decrease the occurrence and/or morbidity of chronic inflammatory diseases and atherosclerosis (Simopoulos, 2002). Encouraging the EPA and DHA intake through the ordinary foods seems to be a better approach than relying on fish based foods alone or fish oil capsules. Intake through common foods will reduce the risk of EPA

Abbreviations: AA, Amino acid; **EPA,** eicosapentaenoic acid; **DHA,** docosahexaenoic acid; **PUFA,** polyunsaturated fatty acids.

Table 1. Fatty acid composition (g/kg diet) of experimental diets.

Fatty acid composition	Grower diet			Finisher diet		
	PO[1]	SO	FO	PO	SO	FO
C14:0	1.5	0.2	3.2	1.5	0.1	3.1
C16:0	58.6	10.7	20.4	59.5	10.2	19.91
C16:1	0.9	0.5	4.5	0.8	0.3	4.31
C18:0	6.1	3.5	4.3	6.1	3.4	4.2
C18:1c	54.3	23.7	31.4	55.0	23.2	30.9
C18:2c	23.9	49.4	15.8	24.9	50.1	16.5
C18:3 alpha	0.02	0.02	0.12	0.02	0.02	0.11
C18:3 gamma	0.3	0.3	1.1	0.2	0.2	1.07
C20:0	0.0	0.0	0.1	0.0	0.0	0.14
C20:5 n-3	0.4	0.2	4.1	0.2	0.1	4.0
C22:6 n-3	0.9	0.5	9.8	0.5	0.2	9.5
n6/n3	18.3	69.0	1.2	34.9	157.2	1.3

[1]PO = Diet containing palm oil, SO = Diet containing 7% soybean oil, FO = Diet containing 7% fish oil.

and DHA peroxidation during storage, as compared with fish oil capsules.

The aim of this research was to study variations in the correlation coefficients between a range of fatty acids and the ratio between n-6 and n-3 fatty acid concentrations.

MATERIALS AND METHODS

One-day-old ROSS 308 broiler chicks were fed a typical corn-soybean meal broiler starter diet for the 1 to 10 days. At 11 days of age, the broiler chicks were allocated to 28 floor pens, with 20 birds per pen.

Experimental diets

At 11 days of age, the birds were randomly assigned to 1 of the 3 dietary treatments containing 7% soybean oil (SO), 7% fish oil (FO) or a more saturated dietary fat containing about 12% palm oil (PO) (Table 1).

The higher palm oil inclusion rate was because of its lower metabolizable energy content. The experimental grower and finisher diets were used during 11 to 28 and 29 to 42 days of age, respectively. The experimental diets were formulated to supply the nutrients requirements levels recommended by ROSS 308 broiler chickens raring guidelines and were fed in mash form. The birds had free access to water and feed. Table 1 shows the fatty acid composition of experimental diets.

Tissue sampling

At 42 days, 2 male birds from each pen (8 birds per treatment) were randomly selected and slaughtered. The total breast and thigh tissues were removed and stored in a deep freezer at −20°C until use.

Fatty acid profile determination

Total lipids were extracted from ingredients according to the method of Folch et al. (1957) and preparation of methyl esters from lipid for gas chromatography was carried out according to Metcalf et al. (1966).

Gas liquid chromatography

Gas chromatography conditions were: Gas Chromatograph model, Agilent 6890; Column: BPX-70: 120m, 250 µm i.d., 0.2 µm film thickness, and carrier gas: nitrogen with inlet pressure: 33.3 psi. Injection port temperature: 250°C, Detector: FID, temperature: 280°C, Oven temperature: 198°C (ISO thermal).

Statistical analysis

The data sets of completely randomized design with 3 treatments and 8 chickens as replicate were compared in the treatments using the one-way analysis of variance (ANOVA) procedure. Significant means were then elucidated using the Duncan multiple range tests. All statistical tests were conducted at 95% confidence level using the SAS program (SAS, 9.1, 2002). The correlation coefficients were estimated by the correlation function in Microsoft Excel.

RESULTS AND DISCUSSION

The mean concentrations of the various fatty acids in broiler thigh and breast tissues are shown in Table 2.

The main fatty acids in broiler breast and thigh tissues were oleic acid (with means of 336 and 348 mg/g extracted oil for breast and thigh tissues, respectively), palmitic acid (with means of 244 and 246 mg/g extracted oil for breast and thigh tissues, respectively), linoleic acid (with means of 155 and 157 mg/g extracted oil for breast and thigh tissues, respectively), LA and stearic acid (with means of 89 and 87 mg/g extracted oil for breast and thigh tissues, respectively) (Table 2). Palmitoleic acid was also a relatively abundant fatty acid (with means of 24 mg/g extracted oil for both breast and thigh tissues). The results are comparable with a previous study (Haug et al., 2010). The ratios between the n-6 and n-3 fatty acids are also demonstrated in Table 2.

The ratio of n-6 and n-3 fatty acids in chicken muscle is reported to be in the range of 8-13:1 (DTU, 2009; USDA, 2009). In the present study, with experimental diets containing 7% fish oil, the broiler breast and thigh meats had a much lower and more favorable ratio between total n-6 and n-3 fatty acids; being about 0.6:1 and 0.9:1, and the

Table 2. Fatty acid composition of breast tissue (percentage of extracted oil).

Parameter	C12:0	C14:0	C16:0	C16:1	C18:0	C18:1c	C18:2c	C18:3 gamma	C20:0	C18:3 alpha	C20:4 n-6	C22:0	C20:5 n-3	C24:0	C22:5 n-3	C22:6 N-3
Breast tissue																
SO	0.0	0.5^{bc}	21.9^{bc}	4.5^{b}	9.4^{d}	29.6^{b}	24.1^{b}	0.2	0.1	2.0^{a}	1.5^{a}	2.9^{a}	0.1^{c}	0.5	0.3^{c}	0.1^{c}
Palm	0.1	0.8^{ab}	27.4^{a}	3.1^{c}	6.7^{e}	41.8^{a}	14.4^{d}	0.1	0.1	0.5^{b}	0.6^{c}	2.1^{ab}	0.1^{c}	0.3	0.1^{c}	0.2^{c}
FO	0.0	1.3^{a}	23.0^{b}	6.8^{a}	7.2^{de}	29.8^{b}	10.4^{e}	0.1	0.1	2.0^{a}	0.3^{d}	0.6^{c}	5.7^{b}	0.0	1.6^{b}	8.7^{ab}
SEM	0.05	0.08	1.27	0.55	0.84	1.86	0.87	0.51	0.13	0.23	0.12	0.23	0.74	0.25	0.19	0.72
Thigh tissue																
SO	0.0	0.4^{c}	20.2^{c}	3.5^{b}	8.9^{c}	33.0^{b}	25.2^{a}	0.2	0.2	2.3^{a}	1.3^{a}	2.3^{b}	0.1^{d}	0.3^{b}	0.2	0.1^{b}
Palm	0.3	0.8^{b}	25.6^{b}	4.0^{b}	6.8^{c}	42.5^{a}	14.3^{b}	0.1	0.1	0.5^{d}	0.5^{c}	1.9^{bc}	0.1^{d}	0.3^{b}	0.2	0.3^{b}
FO	0.1	1.4^{a}	25.1^{b}	8.2^{a}	6.8^{c}	32.2^{b}	10.5^{b}	0.1	0.1	1.8^{bc}	0.4^{c}	0.5^{d}	5.3^{a}	0.0^{c}	0.4	4.6^{a}
SEM	0.1	0.11	0.65	0.63	1.15	1.81	1.70	0.12	0.27	0.12	0.09	0.31	0.13	0.05	0.41	0.56

a-d: Means with different superscripts within column differ significantly at P<0.05. [1]PO = Diet containing palm oil, SO = diet containing 7% soybean oil, FO = diet containing 7% fish oil. SEM, Standard error mean.

ratio between AA and EPA was about 0.06:1 and 0.07:1, respectively.

The ratio of AA to EPA was 16.3:1 and 11.5 in breast and thigh tissues of the birds with the highest ratio in fed diet containing 7% soybean oil, this high difference shows that there is a significant variation among the treatments. It is also interesting to note the concentration of AA vary from 0.34 to 1.47% of extracted oil in breast muscle of birds fed diets with 7% fish oil or soybean oil, respectively; and for thigh muscle, these values were 0.39 to 1.26, respectively. It is a reasonable assumption, that this variation may have feed causes. This could result to the possibility of manipulating the chicken meat to make the chicken meat even more favorable for the health of the consumer. The associations (correlation coefficients) between various fatty acids are shown in Tables 3 and 4.

The concentration of the dominant fatty acid in broiler breast muscle, oleic acid was strongly and positively correlated to those of the saturated fatty acid C:12 (r = 0.72) and weakly and positively correlations with C14:0 (r = 0.23), C16:0 (r = 0.59) and also to monounsaturated fatty acid 16:1 (r = 0.35). However, in thigh tissue, these correlation coefficients between oleic acid and C12:0, C14:0, C16:0 and C16:1 were 0.74, 0.60, 0.85 and 0.71, respectively; which are stronger as compared to the breast muscle.

Oleic and palmitoleic acids are fatty acids produced by desaturation with the delta-9 desaturase enzyme. A high negative correlation coefficient between oleic acid and stearic acid (C18:0) was observed in breast tissue (r = -0.77) but this correlation was not seen in the thigh

Table 3. Coefficients of correlations between fatty acids in chicken breast muscle.

Parameter	C12:0	C14:0	C16:0	C16:1	C18:0	C18:1t	C18:1c	C18:2c	C18:3 gamma	C20:0	C18:3 alpha	C20:1	C20:4 n-6	C22:0	C20:5 n-3	C24:0	C24:1	C22:5 n-3	C22:6 n-3
C12:0	1.00																		
C14:0	0.34	1.00																	
C16:0	0.56	0.72	1.00																
C16:1	0.23	0.80	0.56	1.00															
C18:0	-0.52	-0.58	-0.62	-0.77	1.00														
C18:1t	-0.20	-0.26	-0.33	-0.54	0.54	1.00													
C18:1c	0.72	0.23	0.59	0.35	-0.77	-0.33	1.00												
C18:2c	-0.33	-0.67	-0.68	-0.46	0.22	0.30	-0.24	1.00											
C18:3 gamma	-0.02	-0.26	-0.13	0.08	-0.39	-0.26	0.24	0.70	1.00										
C20:0	-0.41	-0.64	-0.67	-0.61	0.60	0.63	-0.30	0.47	-0.07	1.00									
C18:3 alpha	-0.40	0.07	-0.34	0.26	-0.16	0.01	-0.32	0.46	0.52	-0.05	1.00								
C20:1	-0.51	-0.81	-0.94	-0.62	0.56	0.37	-0.47	0.77	0.28	0.63	0.34	1.00							
C20:4 n-6	-0.30	-0.57	-0.35	-0.21	-0.02	-0.11	-0.02	0.76	0.82	0.23	0.45	0.51	1.00						
C22:0	-0.15	-0.75	-0.66	-0.48	0.17	0.05	0.02	0.75	0.61	0.47	0.25	0.79	0.74	1.00					
C20:5 n-3	-0.33	0.36	-0.12	0.30	0.11	-0.34	-0.52	-0.38	-0.41	-0.29	0.32	-0.08	-0.31	-0.33	1.00				
C24:0	-0.18	-0.73	-0.76	-0.55	0.37	0.40	-0.11	0.74	0.40	0.65	0.17	0.87	0.50	0.89	-0.42	1.00			
C24:1	-0.30	-0.53	-0.81	-0.48	0.57	0.37	-0.37	0.41	-0.06	0.66	0.03	0.74	0.12	0.62	0.01	0.81	1.00		
C22:5 n-3	-0.39	-0.46	-0.55	-0.43	0.42	0.31	-0.46	0.34	-0.11	0.24	0.15	0.56	-0.06	0.10	0.09	0.23	0.13	1.00	
C22:6 N-3	-0.12	0.18	-0.04	0.16	-0.11	-0.31	-0.26	0.10	0.01	-0.15	0.09	-0.12	0.06	-0.17	0.43	-0.30	-0.10	-0.03	1.00

tissue (r = 0.03). This can be explained by the fact that stearic acid is converted to oleic acid by the delta-9 desaturase enzyme and apparently, this relationship occurred in the thigh tissue. EPA and DHA correlates negatively to the C20:0, C22:0 and C24:0 fatty acids. This suggests that these long chain n-3 polyunsaturated fatty acids (PUFAs) might inhibit elongation.

Thus, the enrichment of broiler meat in the

Table 4. Coefficients of correlations between fatty acids and some fatty acid ratios in chicken thigh muscle.

Parameter	C12:0	C14:0	C16:0	C16:1	C18:0	C18:1t	C18:1c	C18:2c	C18:3 gamma	C20:0	C18:3 alpha	C20:1	C20:4 n-6	C22:0	C20:5 n-3	C24:0	C24:1	C22:5 n-3	C22:6 N-3
C12:0	1.00																		
C14:0	0.39	1.00																	
C16:0	0.61	0.86	1.00																
C16:1	**0.33**	**0.87**	**0.78**	**1.00**															
C18:0	-0.06	0.16	0.20	-0.06	1.00														
C18:1t	-0.04	0.12	0.08	-0.17	0.66	1.00													
C18:1c	0.74	0.60	0.85	0.71	0.03	-0.07	1.00												
C18:2c	0.07	0.03	0.23	0.17	0.36	0.15	0.43	1.00											
C18:3 gamma	0.20	0.16	0.40	0.37	0.05	-0.16	0.61	0.88	1.00										
C20:0	-0.19	-0.27	-0.21	-0.20	0.50	0.48	0.02	0.52	0.21	1.00									
C18:3 alpha	-0.14	0.48	0.38	0.57	0.25	0.11	0.34	0.64	0.67	0.17	1.00								
C20:1	-0.37	-0.55	-0.58	-0.38	0.30	0.19	-0.26	0.53	0.25	0.66	0.24	1.00							
C20:4 n-6	-0.06	-0.11	0.16	0.13	0.14	-0.11	0.36	0.88	0.90	0.37	0.59	0.43	1.00						
C22:0	0.14	-0.40	-0.17	-0.18	0.10	-0.07	0.27	0.73	0.67	0.54	0.26	0.73	0.72	1.00					
C20:5 n-3	-0.16	0.63	0.28	0.53	0.28	-0.05	-0.02	-0.11	-0.16	-0.21	0.47	-0.16	-0.20	-0.41	1.00				
C24:0	0.02	-0.52	-0.41	-0.36	0.17	0.21	0.02	0.50	0.32	0.66	0.05	0.85	0.39	0.86	-0.49	1.00			
C24:1	-0.18	-0.35	-0.47	-0.30	0.39	0.32	-0.21	0.22	-0.08	0.67	-0.03	0.79	0.03	0.52	-0.04	0.80	1.00		
C22:5 n-3	-0.33	-0.19	-0.37	-0.14	0.11	-0.43	-0.41	-0.31	-0.34	-0.15	-0.08	0.17	-0.24	-0.10	0.53	-0.12	0.24	1.00	
C22:6 N-3	-0.18	0.54	0.20	0.46	0.15	-0.25	-0.09	-0.25	-0.24	-0.33	0.30	-0.27	-0.31	-0.50	0.94	-0.58	-0.11	0.66	1.00

of arachidonic acid which is now too high in human foods.

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