Effects of Dietary Fish Oil on the Contents of Eicosapentaenoic Acid and Docosahexaenoic Acid and Sensory Evaluation of the Breast Meat in Mule Ducks*

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ABSTRACT : The objectives of this study were to investigate the effects of dietary fish oil inclusion on the eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) contents and organoleptic characteristics of breast meat in mule ducks. Three hundred mule ducks at four weeks of age were randomly assigned to three dietary treatments with five replicate pens in each. One replicate pen had ten males and females each with a total of 100 ducks in each treatment. The diet in the three treatments contained 0, 1.5, and 3.0% fish oil, respectively. Body weights at 4, 6, 8, and 10 weeks of age, and feed efficiency at 4 to 6, 6 to 8, and 8 to 10 weeks of age were recorded. At 10 weeks of age, one male and one female from each replicate were sacrificed for oxidative stability of breast meat and the sacrificed males were employed for the analysis of fatty acids in breast meat and skin. Sensory evaluation of breast meat was also performed. A level of 3.0% fish oil in the diet significantly deteriorated feed efficiency and body weight gain. Dietary fish oil inclusion had a trend of increasing abdominal fat deposition and decreasing the flavor of breast meat. The EPA and DHA contents in the breast meat were higher than those in the breast skin irrespective of oil sources. The EPA and DHA contents in breast meat and breast skin was significantly increased in the 3.0% fish oil group. Although EPA and DHA were not efficiently deposited in the duck meat through dietary fish oil inclusion, this method can still provide a partial supplementation of EPA and DHA. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 2 : 231-235)***

Key Words : Fish Oil, EPA, DHA, Breast Meat, Mule Duck

INTRODUCTION

Consumers tend to demand products of healthy quality. It has been well known that EPA and DHA have associations with decreased risk of coronary heart disease and with reduced levels of plasma triacylglycerides and cholesterol (Harris, 1997). In addition, they have functions of decreasing blood pressure and inhibiting growth of cancer cells (Knapp, 1989; Dwyer, 1997). They are also important in early neural development (Uauy et al., 1996). Both EPA and DHA can be enriched with fish oil inclusion in the poultry diet, and the contents of EPA and DHA deposited in the poultry egg and meat increase with the fish oil level supplemented (Huang et al., 1990; Farrell, 1991; Marshall et al., 1994; Cherian et al., 1996; Leskanich and Noble, 1997; Chen et al., 2000; Akiba et al., 2001; Chen and Hsu, 2003; Lien et al., 2003; Chen and Hsu, 2004). However, increased deposition of EPA and DHA imparts fishy odor and off-flavor to some extent in the products, thus reducing overall acceptance (Miller et al., 1969; Suk et al., 1994). When Pekin ducks were fed diet having 3.5% fish oil for four weeks, levels of EPA and DHA in the meat were at 1.2-1.4% (Farrell, 1991). The mule duck provides the majority of duck meat consumption in Taiwan. The growth curve and pattern of fat deposition in meat are different between mule and Pekin ducks (Scott and Dean, 1991; Li et al., 1999; Jan, 2000). Moreover, flavor and oxidative stability of duck meat produced through fish oil supplementation in the diet is still unknown. The objectives of this study were to investigate the effects of dietary fish oil on the growth performance and contents of EPA and DHA in the meat. The oxidative stability and sensory evaluation in the breast meat were also measured.

MATERIALS AND METHODS

Mule ducks (Muscovy ♂×Kaiya ♀; Kaiya is the progeny of Pekin ♂×white Tsaiya duck ♀) at four weeks of age were randomly assigned to three treatment groups with five replicate pens in each. Twenty ducks with 10 in either gender were raised in each replicate pen with a total of 100 ducks in each treatment. Birds in the three treatment groups were assigned an isonitrogenous and isocaloric diet with 0, 1.5, and 3.0% pollock fish oil, respectively. The control

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Table 1. Composition of experimental diet for mule ducks between 4 and 10 weeks of age

Ingredient	Treatment		
	Control	1.5% Fish oil	3.0% Fish oil
Yellow corn (%)	64.44	64.28	59.70
Soybean meal (CP 44%) (%)	17.90	17.92	18.74
Wheat bran (%)	10.00	10.00	10.00
Fish meal (65%) (%)	1.20	1.20	1.20
Powdered yeast (%)	1.50	1.50	1.50
Rice hull (%)	0.56	0.70	2.98
Soybean oil (%)	1.50	0	0
Fish oil (%)	0	1.50	3.00
Limestone, pulverized (%)	0.50	0.50	0.48
Dicalcium phosphate (%)	1.50	1.50	1.50
Vitamin premix[1] (%)	0.30	0.30	0.30
Mineral premix[2] (%)	0.20	0.20	0.20
L-lysine·HCl (78%) (%)	0.10	0.10	0.10
Iodized salt (%)	0.30	0.30	0.30
Total (%)	100	100	100
Calculated value			
CP (%)	16.02	16.02	16.02
ME (kcal/kg)	2,902	2,902	2,902
Ca (%)	0.73	0.73	0.73
Total P (%)	0.60	0.60	0.60

[1] Vitamins supplementation per kg of diet: Vitamin A, 10,000 IU; vitamin D_3, 1,000 IU; vitamin E, 25 IU; vitamin K, 3 mg; thiamin, 3 mg; riboflavin, 5 mg; pyridoxine, 3 mg; vitamin B_{12}, 0.03 mg; Ca-pantothenate, 10 mg; niacin, 50 mg; biotin, 0.1 mg; folic acid, 3 mg; Choline-Cl (50%), 1,500 mg.

[2] Minerals supplementation per kg of diet: Mn, 60 mg; Zn, 60 mg; Cu, 5 mg; Se, 0.1 mg.

group refers to the 0% fish oil inclusion in this context. The composition of experimental diets is shown in Table 1, and metabolizable energy and crude protein are 2,902 kcal/kg and 16.02%, respectively. Ethoxyquin (1,2-dihydro-6-ethoxy-2,2,4-trimethyl-quinoline) was added at a level of 0.1% of fish oil supplementation.

Body weights were measured biweekly after onset of this study without restriction of feed and water before measurement. Feed efficiency at 4 to 6, 6 to 8, and 8 to 10 weeks of age was recorded. When ducks reached 10 weeks of age, one duck of each gender was randomly sampled and sacrificed to investigate the dressing percentage and weights of abdominal fat. The dressing percentage represents the bled, plucked, eviscerated carcass weight divided by the live weight. The abdominal fat refers to the adipose tissue extending within the ischium, surrounding the cloaca, and close to the abdominal muscle.

For the determination of oxidative stability of meat, 10 g of minced skinless breast meat was taken and mixed with 25 ml trichloroacetic acid (20%) and 20 ml distilled water, and then homogenized at 10,000 rpm for 2 min. The homogenate was then centrifuged for 20 min (1,000×g) and the resulting supernatant was filtered through Whatman #1 filter paper. A mixture of 2 ml of filtrate and 2 ml of barbituric acid (0.02 M) was water bathed at 100°C for 30 min and then cooled down with running tap water for 10 min. The TBA value (expressed as mg malonaldehyde/kg) was measured with a spectrophotometer (Jasco V-500, Japan) at 532 nm (Faustman et al., 1992).

To evaluate the organoleptic characteristics of breast meat, it was heated in an automatic smokehouse until its central temperature reached 75°C, and then cut into a slice of 0.4 cm. Twelve panelists participated in the sensory evaluation of fish odor, flavor, juiciness, and overall acceptance. Hedonic scale (1 to 9) was used, in which the highest indicates the highest degree of preference except for the fishy odor. In contrast, the highest score in the fishy odor represents the breast meat having the strongest fishy odor.

Breast meat and skin from the sacrificed males of 40 and 15 g, respectively, were lyophilized and ground into powder for the analysis of fatty acids. The fat in the sample was extracted with ethyl ether. A small portion of the extracted fat was converted to methyl esters by esterification with BF_3-MeOH (AOAC, 1998). Fatty acids were analyzed using a gas chromatography (Hitachi G-5000, Japan) equipped with a capillary column (Restek, Rtx-2330, USA). The initial temperature was 160°C and increased by 2°C/min to 225°C and then maintained for 2 min. The temperature of injector and the detector remained stably at 260°C. The carrier gas was nitrogen with a flow rate of 5 kg/cm^2.

The body weight, weight gain, and carcass traits were obtained from an individual duck. The feed intake and feed efficiency were obtained from pen values. Data of relative abdominal fat, EPA and DHA contents, and sensory scores were transformed with square root before ANOVA was performed. ANOVA was performed directly for other data. Duncan's multiple range analysis was performed to determine the difference between mean values of treatment groups (SAS, 1988).

RESULTS AND DISCUSSION

Body weight was not significantly affected until fish oil inclusion was at 3.0% level, while feed efficiency was reduced at 1.5% fish oil inclusion (Table 2). There was no difference observed for the body weight in the 1.5% fish oil group compared with the control group (Table 2). However, body weight in the 3.0% group was significantly less than that in the control group after four weeks of treatment. When broilers were fed a diet with 1.5% fish oil for two weeks (5 to7 weeks of age), body weight was not reduced (Gonzalez-Esquerra and Leeson, 2000). In turkey study, body weight was not reduced when they were fed a diet containing 5% fish oil for nine weeks (2 to 10 weeks of age) (Neudoerffer and Lea, 1966). The body weight gain of

Table 2. Effects of dietary fish oil inclusion on body weight, body weight gain, feed intake, and feed efficiency in mule ducks[1]

Age (week)	Treatment		
	Control	1.5% Fish oil	3.0% Fish oil
	Body weight (g)		
4	755±93	750±96	755±89
6	1,379±165	1,372±159	1,353±151
8	1,975±184[a]	1,972±197[a]	1,913±204[b]
10	2,367±233[a]	2,341±221[ab]	2,277±223[b]
	Body weight gain (g)		
4-6	623±109	621±91	598±99
6-8	587±79[a]	601±86[a]	554±118[b]
8-10	392±109[a]	373±85[ab]	363±79[b]
	Feed intake (g/bird/day)		
4-6	142±8	144±10	144±8
6-8	179±13	186±9	186±15
8-10	172±10	177±9	177±7
	Feed efficiency		
4-6	3.20±0.12	3.25±0.13	3.39±0.20
6-8	4.28±0.37	4.35±0.38	4.72±0.36
8-10	6.03±0.41[b]	6.65±0.23[a]	6.74±0.47[a]

[1] Values refer to means±SD. For body weight and body weight gain, n = 100. Feed intake and feed efficiency, n = 5.

[a, b] Data within the same row with different superscripts are significantly different ($p<0.05$).

Table 3. The dressing percentage and abdominal fat of the 10-week-old mule ducks fed diets containing different levels of fish oil[1]

Trait	Treatment		
	Control	1.5% Fish oil	3.0% Fish oil
Live wt (g)	2,279±32	2,357±66	2,218±51
Dressing percentage	73.3±0.6	74.2±0.5	73.9±0.5
Abdominal fat wt (g)	10.8±2.9[b]	24.7±3.1[a]	18.3±3.2[ab]
Relative abdominal fat wt (%)[2]	0.5±0.1[b]	1.1±0.2[a]	0.8±0.1[ab]

[1] Values refer to means±SD. n = 10.

[2] Relative abdominal fat wt refers to abdominal fat weight as percentage of live weight.

[a, b] Data within the same row with different superscripts are significantly different ($p<0.05$).

Table 4. Effects of dietary fish oil on TBA value of breast meat of mule ducks at 10 weeks of age[1]

Treatment	TBA (mg malonaldehyde/kg)
Control	0.52±0.05[a]
1.5% Fish oil	0.63±0.07[a]
3.0% Fish oil	0.63±0.05[a]

[1] Values refer to means±SD. n = 10.

[a] Data within the same column with the same superscripts are not significantly different ($p>0.05$).

3.0% group in 6 and 10 weeks of age was less than that of the control (Table 2). L'opez-Ferrer et al. (1999) reported that body weight gain was not significantly changed when broilers were fed a diet containing 8.2% fish oil for five weeks. Apparently, avian species, the period of feeding diets with fish oil, as well as dietary fish oil levels affect growth performance of poultries. Feed intake was not different among dietary fish oil inclusion (Table 2). However, feed efficiency deteriorated with dietary fish oil inclusion (Table 2). Reduced feed intake was observed in the turkey study, but not in the broiler study (Neudoerffer and Lea, 1966; Gonzalez-Esquerra and Leeson, 2000). The reduced body weight gain in the 3.0% fish oil group was associated with deteriorated feed efficiency, rather than feed intake. Dressing percentage was not changed by dietary fish oil inclusion (Table 3). The fish oil treatment seems to increase deposition of abdominal fat.

The richness of polysaturated fatty acids in fish oil deteriorates its oxidative stability. A trend of increasing oxidation of breast meat was observed although ethoxyquin was added in the diet ($p>0.05$)(Table 4). It has been reported by Neudoerffer and Lea (1967) that ethoxyquin did not change the fatty acid composition of muscle lipid fractions. Increased oxidation of fat was observed in studies of turkeys and humans consuming diet containing fish oil (Neudoerffer and Lea, 1966; Allard et al., 1997). It was noteworthy that the percentage of total saturated fatty acids in the breast meat of mule ducks was similar to those of broilers. However, there were approximately 20% more monosaturated fatty acids in the breast meat of mule ducks compared to those of broilers (54.6 vs. 34.5%), with the expense of polysaturated fatty acids (Ratnayake et al., 1989; Baeza, 1999; Jan, 2000).

Contents of EPA and DHA in the breast meat were significantly higher than those in the breast skin irrespective of soybean oil or fish oil in the diet (Table 5). Most of the EPA and DHA are stored in the phospholipids of cell membranes (Pond et al., 1995; Klasing, 1998), which may explain higher percentages of EPA and DHA in the breast meat than those in the breast skin. Deposition of EPA and DHA in the breast skin was more efficient than that in the breast meat (Table 5). EPA content in the breast meat of the 1.5% fish oil group was increased only by 7.7% over the control compared to an increase of 31.6% in the breast skin. The same pattern was also observed in DHA content in the breast compared to that in the breast skin (Table 5). This was in accordance with previous reports that adipose tissue more closely reflected the lipid composition of the diet than did muscle tissue (Miller and Robisch, 1969; Yau et al., 1991). When broilers were fed a diet with fish oil inclusion, the highest distribution of ω3 fatty acids was in the liver, followed by breast meat, leg meat, and adipose tissues (Miller et al., 1969). Among the ω3 fatty acids, linolenic acid inclined to deposit in the dark meat, whereas EPA and DHA tended to be observed in the white meat (Gonzalez-Esquerra and Leeson, 2000). In the broiler study, the increased deposition of ω3 fatty acids was associated with a

Table 5. Effects of dietary fish oil inclusion on the EPA and DHA contents in the breast meat and skin of mule ducks at 10 weeks of age[1]

Fatty acid[2]	Treatment		
	Control	1.5% Fish oil	3.0% Fish oil
Breast meat			
EPA (%)[3]	0.20±0.08[b]	0.21±0.03[b]	0.55±0.05[a]
DHA (%)	0.07±0.02[b]	0.14±0.02[a]	0.15±0.02[a]
Breast skin			
EPA (%)	0.11±0.03[b]	0.15±0.05[b]	0.55±0.03[a]
DHA (%)	Trace (0.01)[c]	0.03±0.01[b]	0.09±0.04[a]

[1] Values refer to means±SD of 5 males. EPA and DHA refers to eicosapentaenoic acid and docosahexaenoic acid, respectively.
[2] EPA and DHA refer to eicosapentaenoic acid and docosahexaenoic acid, respectively.
[3] Values refer to the designated fatty acid as percentage of total fatty acids.
[a, b, c] Data within the same row with different superscripts are significantly different ($p<0.05$).

decrease of ω6 fatty acids (Ratnayake et al., 1989). The content of EPA in the breast meat and breast skin was only slightly increased in the 1.5% fish oil group compared with 3.0% fish oil group. In contrast to EPA, DHA content in the breast meat and skin, respectively, was increased by 1.1 and 4.2 folds in the 1.5% fish oil group over that in the control (Table 5). The highest level of EPA and DHA in the breast meat was 0.55 and 0.15% (3.0% fish oil group), respectively. Farrell (1991) reported that a level of EPA and DHA was 1.4 and 1.2%, respectively, in the carcass of Pekins fed the diet with 3.5% fish oil for 14 days followed by diet with 7.0% fish oil for 8 days. In addition to fish oil level included in the diet, age and species of ducks may also lead to the different degrees of EPA and DHA deposition in mule and Pekin ducks.

In the sensory evaluation of breast meat (with skin), the flavor in the 3.0% fish oil group was significantly reduced when compared with that in the control and 1.5% fish oil groups (Table 6). The dietary fish oil inclusion resulted in a lower rating of fish odor, flavor, and overall acceptance in a dose-response relationship (Table 6). A similar decrease of flavor was also noted in the broiler study at 5% fish oil (Miller et al., 1967). When 12% redfish meal was included in the diet, no significant difference in flavor or taste was noticed in white meat of both male and female broilers (Ratnayake et al., 1989). In addition to the fish odor in the fish oil, oxidation of ω3 polysaturated fatty acids to some extent contributes to the off-flavor of products (Van Elswyk et al., 1995). The decrease of flavor and overall acceptance in the present study appeared to be associated with fish odor and oxidation of fatty acids (Tables 4 and 6). It has been reported that the organoleptic scores are highly significantly correlated with levels of EPA, docosapentaenoic acid, and DHA (Miller et al., 1969).

In the 1.5% fish oil group, EPA content in the male's breast meat and skin was only slightly increased. However, DHA content was increased by 1.1 and 4.2 folds over the control in the breast meat and skin of males, respectively. Body weight gain, oxidative stability of breast meat, and scores of sensory evaluation were not significantly adversely affected by 1.5% fish oil inclusion in the diet. Although EPA and DHA were not efficiently deposited in the duck meat through dietary fish oil inclusion, this method could still partially supplement EPA and DHA for human food.

Table 6. Scores of sensory evaluation for breast meat of mule ducks at 10 weeks of age[1]

Trait	Treatment		
	Control	1.5% Fish oil	3.0% Fish oil
Fishy odor	3.0±0.5	3.2±0.5	4.1±0.6
Flavor	5.7±0.4[a]	5.6±0.4[a]	4.4±0.5[b]
Juiciness	5.6±0.5	5.3±0.4	5.7±0.4
Total acceptability	6.2±0.4	5.7±0.4	5.3±0.4

[1] Values refer to means±SD. Hedonic scale (1 to 9) was used, in which the highest indicates the highest degree of preference except for the fishy odor. The highest score in the fishy odor represents the breast meat with strongest fishy odor.
[a, b] Data within the same row with different superscripts are significantly different ($p<0.05$). Sensory evaluation was performed by 12 panelists.

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