Fatty Acid Composition of Nile Tilapia (*OREOCHROMIS NILOTICUS*) and Red Hybrid Tilapia (*OREOCHROMIS MOSSAMBICUS X OREOCHROMIS NILOTICUS*) Reared in Intensive and Extensive Systems

Siti Sarah Jamaudin, [1]MohamedAriff Omar & [1,2]Goh Yong Meng
[1]Department of Veterinary Preclinical Sciences
[2]Ruminant Diseases Research Centre
Faculty of Veterinary Medicine
Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

Abstract

Fish and marine mammals are among the richest sources of long–chain n-3 and n-6 polyunsaturated fatty acids (PUFA) in nature. As farmed fish becomes a major contributor to world fish supplies, hence it is important to maintain the high lipid nutritional quality of the product and to continue to provide large amounts of the health-promoting n-3 and n-6 PUFA to the consumers. Therefore, a study was conducted to examine the nutritional content, mainly fatty acid composition, of Nile (*Oreochromis niloticus* and Red hybrid tilapia *(Oreochromis mossambicus x Oreochromis niloticus*), derived from intensive and extensive culture systems. Twenty-two samples of Nile tilapia and 16 samples of Red tilapia cultured intensively and 10 samples of extensively cultured Nile tilapia were used in this study. All samples were subjected to total fatty acids extraction and their fatty acid compositions were determined using gas liquid chromatography. Results showed no significant differences in the concentration of saturated fatty acids (SFA) between intensively and extensively cultured Nile tilapia. For monounsaturated fatty acids (MUFA), the concentration was higher ($p<0.05$) in the intensively cultured Nile tilapia compared to the extensively cultured Nile tilapia. For n-3 PUFA, the concentration was higher ($p<0.05$) in Nile tilapia from the extensive system compared to Nile tilapia from the intensive system. But for n-6 PUFA, the intensively cultured Nile tilapia had a higher ($p<0.05$) concentration compared to the extensively cultured Nile tilapia. For n-6:n-3 PUFA ratio the intensively cultured Nile tilapia had a higher ratio ($p<0.05$) than the extensively cultured Nile tilapia. The different fatty acid composition of Nile tilapia cultured in different systems could be due to the different types of feed consumed by the fish. Future research could be directed at increasing the PUFA level in tilapia through the manipulation of the PUFA level in the fish diet.

Keywords: tilapia, extensive culture system, intensive culture, polyunsaturated fatty acid, saturated fatty acid

INTRODUCTION

Fish and marine mammals are among the richest sources of n-3 poly unsaturated fatty acids (PUFA) in nature. Freshwater fish generally contained lower proportions of n-3 PUFA than marine fish but contain high proportions of n-6 PUFA. Fish supplies from

marine sources are dwindling due to uncontrolled harvesting, deterioration of the habitat and reduction in fish stock, thus making the catch of marine fish inadequate to meet the increasing demand of fish and fish products. Hence, aquaculture is seen as a significant option in ensuring continued fish protein supplies.

As farmed fish becomes a major contributor to world fish supplies, it is important to maintain the nutritionally high lipid quality of the product and to continue to provide large amounts of the health-promoting n-3 PUFA to the consumers. Studies showed that fish cultured in intensive systems were characterized by increased fat deposition of mainly saturated and monosaturated fatty acid and 18:2 n-6 whereas fish reared in the extensive system contained higher proportions of 18:3 n-3, 20:5 n-3 and 22:6 n-3, the favorable fatty acids for human consumption, higher n-3:n-6 PUFA ratios and lower proportions of 18:2 n-6. The fatty acid composition of the diet influenced the fatty acid composition of the fish muscle, although the differences in fatty acid composition of groups of fish were less than the differences in fatty acid composition of their respective diets (Robin *et al.,* 2003). Fatty acid composition can be changed through manipulation of diets, such as using different feed ingredients of oil seed origin such as linseed and flaxseed oils, or through manipulation of n-3 to n-6 PUFA ratio (Nguyen *et al.,* 2003).Therefore, this study was conducted to examine the nutritional content, mainly fatty acid composition, of Nile tilapia (*Oreochromis niloticus*) and Red tilapia (*Oreochromis mossambicus x Oreochromis niloticus*), derived from intensive and extensive culture systems.

MATERIALS AND METHODS

Fish meat sample

Fifty tilapia fish samples were included in this study consisting of 30 Nile tilapia (*Oreochromis niloticus*); 20 fish from the intensive culture system and 10 fish from an extensive culture system, and 20 Red hybrid tilapia (*Oreochromis mossambicus x Oreochromis niloticus*) from an intensive culture system. All 40 tilapia samples from the intensive culture system with a bodyweight range of 350 to 450 g were purchased from the a wholesale market in Selangor, Malaysia and the fish originated from several farms that had adopted the intensive culture system using earth ponds, where the fish were fed commercial pellets and harvested at about 4 months of age. Another 10 Nile tilapia samples of body weight ranging 200 to 300 g were collected from a former mining pool (extensive system) where the fish were managed minimally and fed natural foods.

Fatty acid profile

All tilapias were filleted at the left dorsal cranial part of the body and shaped into standard size of 5 cm (long) × 3 cm (wide) × 1 cm (thick). Fillets were cut and 1 g samples from the middle portion were taken for total lipid extraction using the chloroform-methanol 2:2 (v/v) solvent system according to the method of Folch *et al.* (1957) modified by Rajion *et al.* (1985). Fatty acids were transesterified to methyl ester with 0.5 N NaOH in methanol and 14% boron trifluoride in methanol. In addition 100 µg of heneicosanoic acid (C 21:0) were added to the methylating tube as an Internal Standard (ISTD) prior to methylation. The methyl esters were quantified using gas

chromatograph GC (Agilent 7890N) on a 100m × 0.2 5mm ID (0.20μm film thickness) Supelco SP- 2560 capillary column (Supelco, Inc., Bellefonte, PA, USA). One microliter

of the sample was injected using an auto-sampler into a chromatograph, equipped with a flame ionization detector (FID) at a split ratio of 10:1. High purity nitrogen (99.999% from an atmospheric nitrogen gas generator) was the carrier gas at 40mL/minute. High purity hydrogen (Dominick Hunter, Parker Hannifin Ltd, UK) and compressed air (Malaysian Oxygen Bhd., Malaysia) were used in the flame ionization detector for the gas-liquid chromatography. The injector temperature was programmed at 250°C and the detector temperature was 300°C. The column temperature programmed included an initial temperature of 150°C held for 2 minutes, and then warmed to 158°C at 1°C/minute which was then held at this temperature for 28 minutes, finally the column was warmed to 220°C at 1°C/minute, and maintained for 20 minutes to achieve optimum separation. The peaks of samples were identified and concentrations calculated based on the retention times and peak areas of known standards (Sigma Chemical Co., St. Louis, Missouri, USA). The fatty acid concentrations were expressed as the percentage of identified total fatty acids measured in each sample. Automatic expression of the peak areas as percentage of a detected fatty acid was obtained with a programmed PC under Microsoft Excel 2000 (Microsoft Corp., Redmond, USA).

Statistical analysis

Data of the fatty acid profile of tilapia fillets grouped by culture systems and species were analyzed for mean differences between groups by an independent sample t-test, using the Statistical Analysis System (SAS) 2000.

RESULTS AND DISCUSSION

The fatty acid profiles of Nile tilapia sampled from extensive and intensive culture systems and between species of Nile tilapia and Red hybrid tilapia are presented in Table 1. The fatty acid composition of Nile tilapia from extensive and intensive culture systems were similar to those reported earlier for tilapia and other fish species (Gonzalez *et al.*, 2006; Fuentes *et al.*, 2010). For the different genotypes of Nile tilapia and Red hybrid tilapia, only 3 types of fatty acids: 14:0, 24:0 and 18:3 n-3, were found to be significantly different. This finding is in agreement with the studies by Teoh *et al.* (2011) who also reported a significant effect of the tilapia genotype for 24:0, 18:3 n-3 and 22:1 n-9. Nile tilapia showed a significantly higher value for 14:0 and a significantly lower value for 18:3 n-3 than the Red hybrid tilapia. However, Teoh *et al.* (2011) showed that the Nile tilapia had lower 14:0 and significantly higher 18:3 n-3 compared to Red hybrid tilapia. They also observed that the net intake of fatty acids was not affected by the tilapia genotype but the dietary lipid sources had significantly affected the fatty acid composition.

The total percentage of SFA and PUFA were higher in extensively cultured Nile tilapia than the intensively cultured Nile tilapia, whereas the Nile tilapia from the intensive culture system showed a higher content of MUFA than Nile tilapia from the extensive culture system. This was probably due to the high content of MUFA in the diet

Table 1. Fatty acid composition of tilapia of different species and culture systems

Fatty acid	Fatty Acid (% Total Fatty Acid)		
	Intensive System		Extensive System
	Nile tilapia[2]	Red hybrid tilapia[2]	Nile tilapia[2]
14:0	4.48[a] ± 0.47	2.54[b] ± 0.17	3.02[b] ± 0.48
15:0	0.46[a] ± 0.10	0.47[a] ± 0.06	0.53[a] ± 0.06
15:1	0.41[b] ± 0.05	0.60[b] ± 0.06	1.08[a] ± 0.18
16:0	23.31[a] ± 0.49	24.74[a] ± 0.85	24.92[a] ± 0.75
17:0	7.03 [a]± 0.84	9.95[a] ± 1.36	8.69[a] ± 1.19
18:0	7.47[b] ± 0.42	6.72[b] ± 0.27	10.82[a] ± 0.64
20:0	0.84[a] ± 0.08	0.77[a] ± 0.13	0.68[a] ± 0.10
22.0	0.96[a] ± 0.09	1.25[a] ± 0.13	0.99[a] ± 0.10
24:0	1.13[b] ± 0.22	2.18[a] ± 0.20	2.75[a] ± 0.42
∑ SFA[3]	46.10[a] ± 0.78	46.40[a] ± 1.16	48.10[a]±1.18
18:1 n-9	29.45[a] ± 1.28	26.47[a] ± 1.41	15.93[b] ± 2.46
24:1	0.79[b] ± 0.07	0.59[b] ± 0.10	2.56[a] ± 0.36
∑ MUFA[3]	31.17 ± 1.08	29.21[a] ± 1.25	19.76 ± 2.03
18:3 n-3 (ALA)[4]	0.89[b] ± 0.08	1.34[c] ± 0.11	2.69[a] ± 0.29
20:5 n-3 (EPA)[4]	1.56[b] ± 0.13	1.21[b] ± 0.09	2.41[a] ± 0.27
22:6 n-3 (DHA)[4]	5.02[b] ± 0.50	4.86[b] ± 0.50	11.90[a] ± 1.54
∑ n-3 PUFA[3]	8.27[b] ± 0.65	8.01[b] ± 0.74	19.57[a] ± 0.65
18:2 n-6 (LA)[4]	10.11[a] ± 0.46	11.68[a] ± 1.18	5.51[b] ± 0.65
18:3 n-6 (GLA)[4]	0.41[a] ± 0.05	0.62[a] ± 0.06	0.52[a] ± 0.14
20:2 n-6 (AA)[4]	3.71[b] ± 0.62	4.03[b] ± 0.36	6.58[a] ± 0.64
22:5 n-6 (DPA)[4]	1.56[b] ± 0.13	1.21[b] ± 0.09	2.41[a] ± 0.27
∑ n-6 PUFA	14.35[a]±0.60	16.32[a] ± 1.23	12.55[b] ± 0.77
∑ Total UFA[3]	53.80[a] ± 0.78	53.55[a] ± 1.16	51.89[a] ± 1.18
n-6 : n-3 ratio	1.88[a] ± 0.10	2.24[a]± 0.20	0.74[b] ± 0.10
UFA/SFA	1.17[a] ± 0.03	1.17[a] ± 0.06	1.09[a] ± 0.05
PUFA/SFA	0.49[b] ± 0.02	0.54[b] ± 0.05	0.68[a] ± 0.07

[ab]Means with different superscripts within row are significantly differences at $p < 0.05$

[2]Nile tilapia (extensive); n=10, Nile tilapia (intensive); n=22, Red tilapia (intensive); n= 16

[3]SFA= Saturated fatty acid; MUFA= Monounsaturated fatty acid; PUFA= Polyunsaturated fatty acid; UFA= Unsaturated fatty acid

[4]LA= Linoleic acid; GLA= γ-Linolenic acid; AA= Arachidonic acid;
DPA= Docosapentaenoic Acid; ALA=α-linoleic acid; EPA=Eicosapentaenoic acid;
DHA= Docosahexaenoic acid

of intensively cultured Nile tilapia. Oleic acid (18:1 n-6) was identified as the major MUFA in Nile tilapia from both intensive and extensive systems. The higher value of oleic acid in intensively cultured fish could be due to the high content of oleic acid in the commercial feed as reported by Fuentes *et al.* (2010) for the sea bass and Gonzalez *et al.* (2006) for the yellow perch.

In this study it was determined that the total SFA was higher ($P>0.05$) in extensively cultured Nile tilapia than intensively cultured Nile tilapia with total SFA of 48.13 and 46.14%, respectively. Palmitic acid (16:0) was the major fatty acid in the Nile tilapia from both extensive and intensive culture systems, followed by stearic acid (18:0). The stearic acid content was also found to be high in other fish species (Chen *et al*., 1995; Fuentes *et al*., 2010).

As for the PUFA content, extensively cultured Nile tilapia had a higher percentage of n-3 PUFA and n-6 PUFA compared with intensively cultured Nile tilapia. Arachidonic acid (20:4 n-6) was the major fatty acid in the n-6 PUFAs. Freshwater fish were reported to contain a higher concentration of arachidonic acid and linoleic acid than marine fish which could be due to dietary effects and saturation and/or elongation mechanisms. The higher concentration of arachidonic acid in Nile tilapia harvested from extensive culture systems could be attributed to the type of diet of the Nile tilapia in the extensive environment which comprised insect larvae, freshwater algae and crustaceans which have high content of linoleic acid and α-linolenic acid (Gonzalez *et al.,* 2006).

Besides that, for the n-3 PUFA, DHA (22:6 n-3) was the major fatty acid in this group, and the DHA and EPA (20:5 n-3) were higher in the extensively cultured Nile tilapia compared to intensively cultured Nile tilapia. This finding is in agreement with Karapanagiotidis *et al.* (2006) for tilapias and Fuentes *et al.* (2010) for the sea bass. For the n-3/n-6 ratio, the values for extensively cultured Nile tilapia were significantly lower ($P<0.05$) compared with intensively cultured Nile tilapia. This finding is contrary to previous reports for fish with n-3/n-6 ratio significantly higher ($P<0.05$) in fish from the extensive system (Fuentes *et al.,* 2010). Although the n-3 PUFA: n-6 PUFA ratio was low but the proportion of n-3 PUFA and n-6 PUFA was still significantly higher in extensively cultured Nile tilapia than in intensively cultured Nile tilapia.

With regards to the PUFA/SFA ratio, higher levels were detected in extensively cultured Nile tilapia compared to intensively cultured Nile tilapia with the values of 0.68 and 0.49, respectively and 0.54 for the Red hybrid tilapia. According to the nutritional guidelines of the Department of Health of the UK (1994), a ratio of 0.45 or more is recommended for a balanced fatty acid intake in a healthy diet.

CONCLUSION

The ratio of the n-3:n-6 PUFAs was higher in tilapia fish from the intensive culture system than the extensive culture system. This difference may be attributed to the dietary content of the Nile tilapia. There was no difference between different tilapia genotypes (Nile vs Red tilapia) for SFA, PUFA, PUFA/SFA and n-3:n-6 ratio since both genotypes were fed similar commercial pellets. It can be concluded that in order to have higher n-3:n-6 PUFA ratios and to have good quality tilapia fish with high content of n-3 PUFA (especially DHA and EPA) content, the content of PUFA in the diet could be increased. This is because fatty acid proportion of fish is very much dependent on the

type of fish diet. From the findings of this study it is evident that extensively cultured and intensively cultured Nile tilapias and also intensively cultured Red hybrid tilapias have high PUFA/SFA ratio that is beneficial to human health.

The knowledge of the fatty acid profile is important and this study provides alternative sources of healthy and high quality foods and the base data about the relationship between the type of management and genotype of tilapia fish with fatty acid concentration. Future research can be directed to increasing the PUFA level in tilapia by manipulating the PUFA level in the fish diet.

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