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RESEARCH ARTICLE

Nutritional properties of kutum, *Rutilus frisii kutum* (Kamensky), silver carp, *Hypophthalmichthys molitrix* (Val.), and rainbow trout, *Oncorhynchus mykiss* (Walbaum), correlated with body weight

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Abstract. The correlation of proximate composition and fatty acid content of the meat of brackish-water kutum, *Rutilus frisii kutum* (Kamensky), warm-water silver carp, *Hypophthalmichthys molitrix* (Val.), and cold-water rainbow trout, *Oncorhynchus mykiss* (Walbaum) were determined in relation to body weight. In silver carp, body protein increased (r = 0.574, P = 0.032) with increased body weight while moisture decreased (r = -0.789, P = 0.000). In kutum and rainbow trout the contents of protein and lipid were independent of fish size (P > 0.05). The n-3 polyunsaturated fatty acids of silver carp meat increased with body weight (r = 0.592, P = 0.033), while n-6 fatty acids decreased (r =-0.667, P = 0.013). The results indicated the important advantages of the nutritional quality of fish of different sizes in the human diet.

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Introduction

Aquatic animals are regarded as valuable sources of animal protein in human diets. The significance of fish lipids in human diets are of great importance because of their content of essential polyunsaturated fatty acids (Puwastien et al. 1999). The health benefits from consuming polyunsaturated fatty acids, especially ecosapentaenoic acid (EPA) and docosahexaenioic acid (DHA), are well documented (Hunter and Roberts 2000, Arts et al. 2001). For health resons, it is recommended to reduce the intake of dietary saturated fatty acids and to increase the consumption of dietary mono- and polyunsaturated fatty acids. This can be accomplished by changing the diet or dietary components (Jiménez-Colmenero 2007). Aquatic ecosystems are known to be the main source of essential polyunsaturated fatty acids, and humans obtain the principle parts of these fatty acids by consuming fish and other marine and freshwater products (Arts et al. 2001). Fish oils play important roles in human nutrition, disease prevention, and promoting health (He 2009).

The fatty acid composition of fish can be affected by several biological factors such as fish size, age, diet, reproductive status, and season (Bandarra et al. 1997, Celik et al. 2005, Özogul et al. 2007). However, there is limited information on the effect fish size can have on the fatty acid composition of its meat (Miliou et al. 2006). Since long chain PUFAs, such as EPA and DHA, are not synthesized in the human body (Ghomi et al. 2012b) and are mostly obtained from marine food (Ghomi and Nikoo 2010) and , it is important to study the composition of fatty acids in farmed species (Ghomi et al. 2012a). Considering the health benefits of the essential polyunsaturated fatty acids, especially EPA and DHA, in fish, it is not well known among consumers which size of fish is more nutritious and healthy. Moreover, several freshwater and brackish water species are available in local markets. It has been reported that the fatty acid composition of freshwater fish species contain higher proportions of n-6 polyunsaturated fatty acids, while in marine species, EPA and DHA are the dominants (Justi et al. 2003). Thus, the objectives of this study were first to analyze the proximate composition and fatty acid content of three commercial fish species – kutum, *Rutilus frisii kutum* (Kamensky), a brackish water species; silver carp, *Hypophthalmichthys molitrix* (Val.), a freshwater species which lives at high water temperatures; rainbow trout, *Oncorhynchus mykiss* (Walbaum), a cold water species, and second to assess the correlation between proximate composition and fatty acid content and body weight.

Material and methods

Fish samples

Fresh semi-intensive cultured silver carp (range: 200-1850 g), semi-intensive cultured rainbow trout (range: 25-500 g), and wild kutum caught in the Caspian Sea (range: 210-1300 g) (n=15 of each) were purchased from local fish markets (Sari, Iran) and transported to laboratory in boxes containing ice. The ratio of fish to ice was 1:2. Upon arrival, the fish were decapitated, gutted, skinned, and washed with tap water to remove blood and slime. Slices from the mid sections of the fish were collected to analyze the proximate composition and fatty acid content. The weight of fishes was recorded to the nearest ± 0.01 g.

Proximate composition

Moisture was determined by drying the samples in an oven (Heraeus, D-63450, Hanau, Germany) at 105°C to a constant weight (AOAC 2005); lipids were extracted according to Kinsella et al. (1977) using chloroform and methanol and expressed as g 100 g^{-1} of wet muscle; crude ash was determined by incineration in a muffle furnace (Isuzu, Tokyo, Japan) at 600°C for 3 h (AOAC 2005); crude protein was determined with the Kjeldahl method (N × 6.25) using an automatic Kjeldahl system (230-Hjeltec Analyzer, Foss Tecator, Höganäs, Sweden) (AOAC 2005).

Fatty acid analysis

The lipid required for fatty acid analysis was first extracted according to Kinsella et al. (1977). Fifty g of sample was homogenized in a blender for 2 min with a mixture of 50 ml chloroform and 100 ml methanol. Then 50 ml of chloroform was added and further homogenized for 30 s. Finally, 50 ml of distilled water was added to the mixture and blended for 30 s. The homogenate was filtered through Whatman No. 4 filter paper into a decanter. The lower fraction was then collected and filtered. It was then transferred to a rotary evaporator (Rotavapor R-114, BÜCHI, Flawil, Switzerland) for solvent evaporation. Then the lipid fatty acids were analyzed. The fatty acid methyl ester (FAME) was prepared as follow: lipid samples (15-20 drops) were diluted with 2 ml of KOH followed by the addition of 5 ml of n-6 in a sealed tube. The mixture was then shaken using a vortex for 1 min, and left for about 20 min until it was separated into two phases. The top layer, FAME, was analyzed using Trace GC (Thermo Finnigan, Italy). The GC conditions were as follows: capillary column (Bpx-70, 60 m, 0.32 mm, i.d. 0.25 μm); the split ratio of 90:1; injection port temperature of 250°C; flame ionization detector temperature of 270°C. Oven temperature was set at 195°C for 75 min. Flow rate of carrier gas (helium) was 1 mL min^{-1} and the makeup gas was N_2 (30 mL min^{-1}). The sample size injected for each analysis was 1 μL.

Statistical analysis

Linear correlations (r) between variables were established using Pearson's coefficient at $P < 0.05$. For mean comparisons, data were analyzed with one-way analysis of variance (ANOVA) and Duncan's multiple range test ($P < 0.05$) by SPSS 16.

Results and discussion

The fatty acid composition of different fish species (kutum, silver carp, rainbow trout) was examined in relation to body weight, and the results are presented in Table 1. In silver carp, the n-3 polyunsaturated fatty acid content increased with increasing fish weight, while n-6 fatty acid content decreased ($P = 0.032$ and $P = 0.013$, respectively) (Table 1). The same results are reported by Miliou et al. (2006) for the common octopus, *Octopus vulgaris* (Cuvier). In this species n-3 PUFA increased with increases in body weight, while n-6 PUFA, saturated, and monounsaturated fatty acids decreased especially at higher temperatures. The fatty acid compositions of the meat of kutum and rainbow trout did not correlate with fish size indicating the importance for human nutrition of the availability in local markets of different sizes of kutum and rainbow trout..

In this study, the content of EPA and DHA in rainbow trout was lower than the values in silver carp and kutum (Table 2). An inverse relationship between temperature and the amounts of unsaturated fatty acids such as EPA and DHA has been noted in several poikilothermic species (Hazel 1984). The decreases in EPA and DHA observed in fish inhabiting low temperatures reflect the higher demand for EPA and DHA for membrane functionality. Moreover, the contents of unsaturated fatty acids were higher in rainbow trout than in silver carp or kutum (Table 2).The reduction in n-3 essential fatty acid content in common octopus, especially at low temperature, was accompanied by increased monounsaturated fatty acids such as oleic acid (Miliou et al. 2006). The increase in unsaturated fatty acid contents at low temperatures is important for membrane function (Olsen et al. 1999, Khériji et al. 2003).

In the present study, kutum had high amounts of MUFAs (47.67 and lower amounts of PUFAs (20.25%) (Table 2). However; the contents of MUFAs in the same species studied by Özogul et al. (2007) was lower, while those of saturated fatty acids (SFAs) were higher. In fact, the fatty acid profiles of individual fish of the same species can be influenced by diet, location, gender, and environmental conditions (Gruger 1967). Diet plays the most important role in fatty acid content. Lenas et al. (2010) noted a strong significant difference between the fatty acid contents in the brain of two wild and cultured fish in sea bass, *Dicentrarchus labrax* (L.), and sea bream, *Sparus aurata* L., which was related to diet. The kutum analyzed in this study contained higher amounts of n-3 fatty acids than n-6 (Table 2), which is similar to the findings of Özogul et al. (2007), although the amounts were lower. Changes in the types and amounts of fatty acids in fish tissues has been attributed to the location, size of the fish, age, food, reproductive status, and season (Bandarra et al. 1997, Celik et al. 2005). The amounts of EPA and DHA in

Table 1
Linear regression coefficients estimated for major classes of fatty acids, EPA and DHA with body weight in kutum (*Rutilus frisii*), silver carp (*Hypophthalmichthys molitrix*), and rainbow trout (*Oncorhynchus mykiss*)

Regression specifications	n-3	n-6	SFA	MUFA	PUFA	EPA	DHA
Kutum							
r	-0.115	0.311	0.125	-0.186	0.255	0.108	-0.336
F	0.12	0.96	0.14	0.32	0.62	0.10	1.14
P-value	0.735	0.353	0.714	0.585	0.449	0.752	0.312
Rainbow trout							
r	0.256	0.267	-0.136	0.234	0.113	0.307	-0.262
F	0.84	0.92	0.22	0.69	0.15	1.25	0.88
P-value	0.376	0.355	0.642	0.420	0.700	0.285	0.365
Silver carp							
r	0.592	-0.667	0.209	0.049	-0.221	0.437	-0.368
F	5.92	8.83	0.50	0.02	0.56	2.59	1.72
P-value	0.033	0.013	0.494	0.873	0.469	0.136	0.216

SFA: Saturated fatty acid; MUFA: Mono unsaturated fatty acid; PUFA: Poly unsaturated fatty acid; EPA: Ecosapentaenoic acid; DHA: Docosahexaenioic acid

Table 2
Major class of fatty acids, EPA and DHA (% of total fatty acids) in kutum (*Rutilus frisii*), silver carp (*Hypophthalmichthys molitrix*), and rainbow trout (*Oncorhynchus mykiss*)*. Data are presented as mean ± SD

Fatty acids	Kutum	Silver carp	Rainbow trout
SFA	18.99 ± 3.32^{b}	23.30 ± 3.59^{a}	16.18±0.85c
MUFA	47.67 ± 4.37^{a}	38.11 ± 4.04^{b}	45.88±2.12a
PUFA	20.25 ± 1.90^{c}	29.74 ± 3.10^{b}	32.23±2.97a
n-3	18.17 ± 3.63^{b}	23.84 ± 4.15^{a}	11.19±1.20c
n-6	1.50 ± 0.75^{c}	5.37 ± 4.80^{b}	20.49±1.08a
EPA	3.95 ± 0.43^{b}	5.11 ± 1.50^{a}	1.51±0.46c
DHA	8.85 ± 2.03^{a}	6.06±1.17b	6.45±0.92b

*Means with the same small letter within a row were not significantly different at P < 0.05
SFA: Saturated fatty acid; MUFA: Mono unsaturated fatty acid; PUFA: Poly unsaturated fatty acid; EPA: Ecosapentaenoic acid; DHA: Docosahexaenioic acid

kutum (12.80%), which is abrackish-water species, were higher than those in rainbow trout and silver carp (Table 2). It has been reported that marine fish species are rich in n-3 fatty acids, especially DHA and EPA, whereas freshwater fish species contain higher amounts of n-6 polyunsaturated fatty acids (Wang et al. 1990, Haard 1992).

The proximate composition of the three studied species in relation to body weight is presented in Table 3. Similar to fatty acid composition, in silver carp, body protein and moisture were significantly correlated with weight ($P < 0.05$) (Table 3). In this species, body protein increased as fish weight increased ($r = 0.574$), but moisture content decreased ($r = -0.789$). However, in kutum and rainbow trout there was no significant correlation ($P > 0.05$) between proximate composition and body weight. The protein content of kutum, silver carp, and rainbow trout slices were 18.3, 15.5, and 17.64%, respectively ($P > 0.05$) (Table 4). Similar amounts of protein were recorded for pike-perch, *Sander lucioperca* (L.) (Celik et al. 2005). The lipid content recorded was between 4.08 and 6.41%, while rainbow trout had a higher amount compared to other species (Table 4). The same amounts of lipid were reported for Indian mackerel, *Rastrelliger kanagurta* (Cuvier), and yellow striped

Table 3
Linear regression coefficients estimated for proximate composition with body weight in kutum (*Rutilus frisii*), silver carp (*Hypophthalmichthys molitrix*), and rainbow trout (*Oncorhynchus mykiss*)

Regression specifications	Protein	Lipid	Moisture	Ash
Kutum				
r	0.463	0.446	-0.531	0.364
F	2.18	1.98	3.92	1.52
P-value	0.178	0.196	0.076	0.245
Rainbow trout				
r	-0.337	0.281	-0.142	-0.331
F	1.40	1.11	0.269	1.60
P-value	0.260	0.311	0.613	0.228
Silver carp				
r	0.574	0.083	-0.789	-0.017
F	5.88	0.063	21.43	0.004
P-value	0.032	0.808	0.000	0.954

Table 4
Proximate composition (protein, lipid, moisture and ash) of meat in kutum (*Rutilus frisii*), silver carp (*Hypophthalmichthys molitrix*). and rainbow trout (*Oncorhynchus mykiss*). Data are presented as mean ± SD

Proximate	Kutum	Silver carp	Rainbow trout
Protein (%)	18.26±2.97[a]	15.50±2.96[a]	17.64±3.77[a]
Lipid (%)	5.48±2.15[ab]	4.08±1.77[b]	6.41±1.43[a]
Moisture (%)	71.93±3.05[b]	76.92±2.56[a]	73.77±2.11[b]
Ash (%)	2.34±0.76[a]	1.75±0.51[b]	2.33±0.67[a]

*Means with the same small letter within a row were not significantly different at P < 0.05

scad, *Selaroides leptolepis* (Cuvier), by Osman et al. (2001) and for striped snakehead, *Channa striatus* (Bloch), by Zuraini et al. (2006). According to the classification suggested by Suriah et al. (1995), silver carp can be regarded as a lean fish with a lipid content below 5%, and which was 4.08% in the current study. The average amount of lipid in kutum in this study (5.48%) is higher than the value obtained for the same species caught in a lake in Turkey (Özogul et al. 2007). The higher amount could result from the skin on the kutum slices in this study, which can increase lipid contents (Katikou et al. 2001). Moreover, some biological and environmental factors such as age, sex, maturity, seasons, location, temperature, and especially diet can affect lipid content (Celik et al. 2005).

Kutum and rainbow trout of different sizes available in local markets had similar contents of essential polyunsaturated fatty acids such as n-3 PUFA, EPA, and DHA. However, larger silver carp is more nutritious for humans. The lower contents of EPA and DHA in rainbow trout can result from both habitat (low water temperature) and diet.

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