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The lipid content and fatty acid profiles in the fattened bluefin tuna *(Thunnus thynnus)* in the Mediterranean Sea

Lipidgehalt und Fettsäureprofil gemästeter Blauflossen-Thunfische (Thunnus thynnus) aus dem Mittelmeer

Abdullah Öksüz

Summary

The lipid contents of different parts of the body and fatty acid profiles of the fattened bluefin tuna (BFT) have been investigated. The lipid content of fattened BFT varied within the body parts. Higher lipid and lower moisture levels were present in kama meat, followed by the ordinary muscle than caudal meat. The liver and viscera of the fattened BFT contained considerable amount of lipid with levels of 62.9 and 84.6 % respectively. Ordinary muscle lipid content and fatty acid profiles of wild and fattened bluefin tunas were found significantly different from each other. The DHA:EPA ratio in the fattened and wild BFT were 1.02 and 5.03 respectively. Ordinary dorsal muscle composition of wild and fattened BFT differed significantly. Ash content was much higher in wild BFT than fattened BFT. The wild BFT had distinctive fatty acid profile, having a high level of DHA:EPA ratio and absence of 22:1n11 fatty acid than the fattened BFT.

Keywords: Atlantic Bluefin tuna, fattened, omega-3, GC-MS, DHA:EPA

Zusammenfassung

Lipidgehalte verschiedener Körperteile und deren Fettsäureprofil von gemästeten Blauflossen-Thunfischen wurden untersucht. Der Lipidgehalt war im gesamten Tierkörper der Blauflossen-Thunfische ungleich verteilt. Höhere Lipidgehalte und geringere Feuchtigkeitswerte wurden in der Muskulatur des ventralen Kopfbereiches gemessen, gefolgt vom Rumpfmuskel und dem Schwanzmuskel. Die Leber und die Eingeweide der gemästeten Blauflossen-Thunfische wiesen eine beträchtliche Menge an Lipiden mit einem Gehalt von 62,9 bzw. 84,6 % auf. Der Lipidgehalt und das Fettsäureprofile des Rumpfmuskels unterschieden sich signifikant bei den wilden und den gemästeten Tieren voneinander. Das DHA:EPA-Verhältnis (Docosahexaensäure:Eicosapentaensäure-Verhältnis) der gemästeten und der wilden Blauflossen-Thunfische betrug 1,02 bzw. 5,03. Die Zusammensetzung des dorsalen Rumpfmuskels unterschied sich signifikant bei den wilden und gemästeten Tieren voneinander. Der Aschegehalt war bei Wild-Blauflossen-Thunfischen deutlich höher als bei den Masttieren. Die wilde Form hatte ein unverwechselbares Fettsäureprofil mit einem hohen DHA:EPA-Verhältnis und bei einer Abwesenheit der Fettsäure 22:1n11.

Schlüsselwörter: Roter Thun, gemästet, Omega-3, Gaschromatographie-Massenspektrometrie, DHA: EPA

Introduction

The Atlantic Bluefin tuna is the native fish species of the Atlantic Ocean and the Mediterranean Sea. Due to its large size and high prize as a food fish, Bluefin tuna (BFT) draws great attentions fish industry. The BFT is one of the main interest of Japanese fish market and they consume about 80 % of all the Bluefin tuna caught worldwide. Generally, Turkish BFT farms export their products to Japan and to lesser extent to the USA either frozen alternatively, or in fresh-chilled form. The fresh-chilled tuna are exported on the same day to the Japanese market by air cargo. According to TUİK, total production of BFT reached to 551.4 tons in Turkey (TUİK, 2015)

The processed BFT are exported as either gilled or gutted (dressed), or filleted or in loins. The remaining parts, namely head, caudal fin, liver, and viscera are considered as by products, but still reasonable amount of meat and oil are recovered from them. The filleting process of BFT results in caudal, head, cheek, and kama meat with a different yield rate. Kama meat (collar) is the part of the fish beneath the gills and around the pectoral fin, and it is delicacy of the Eastern fish restaurant. It is removed during trimming or filleting of BFT. Kama meat yields almost 3.9 % of total body weight.

Proximate composition, including the fatty acid profile of many aqua-cultured fish species has been studied, but limited studies are available specifically on fatty acid composition of wild and fattened BFT. Nutritional quality of BFT is mainly due to its high lipid content and being rich in omega 3 fatty acids. The most expensive sushi is prepared with fatty meat of tuna, known as toro, from the belly and fetches high price. Nutritional quality of tuna lipid is determined not only by its quantity but also its fatty acid composition.

The aim of this study is to determine lipid distribution and fatty acid composition of the various body parts of the fattened BFT. Additionally, wild BFT ordinary muscle (OM) was analysed to understand how lipid content and fatty acid composition differs from the fattened BFT.

Materials and Methods

Sampling

Fattened BFT samples were provided by TSM Deniz Ürünleri, A.Ş in Antalya in October. During tuna processing, eight fish were selected randomly, with a mean weight of 284±85 kg. Samples were taken from ordinary dorsal muscle, caudal part, and recovery meat from head, cheek, kama meat, liver and viscera. Taken samples were packed in a polyethylene bag separately, frozen at –70 °C in the processing plant, and transferred to the laboratory in frozen state. After defrosting the samples in the fridge, triplicate representative samples were drawn from each part for chemical analysis. Wild BFT samples, caught in the north east Mediterranean Sea, were purchased from licensed fishermen.

Determination of proximate composition

Lipid extraction was carried out according to Modified Bligh & Dyer method (Hanson and Olley, 1963). Moisture content of BFT was determined by oven drying method (AOAC, 1990; method no 950.46). Ash content was determined by AOAC (1990) method no 938.08.

Fatty acid analysis

Fatty acid methyl esters (FAMEs) of lipid were esterified as described by Joseph and Ackman (1992). Separation and confirmation of FAME's were done by using a GC-MS (Hewlett Packard, 6890) coupled to a Hewlett Packard (model 5972A, HP 6890 system) MS detector. MS detector was operated on TIC mode. Separations of fatty acids were achieved with HP-INNOWAX column (Model number HP 19091N-133, 0.25 mm * 30 m * 0.25 m) as indicated by Öksuz and Özyilmaz (2010). Identification of fatty acid methyl esters was carried out by using authentic FAME standards (Supelco 47085U, and Supelco 37 component FAME mix 47885-U).

Statistical analysis

The samples were subjected to ANOVA. Differences among the treatments were determined using Duncan's multiple comparison tests.

Results

Proximate composition

Lipid, moisture and ash content are presented in Table 1. The comparison of the wild and the fattened BFT ordinary muscle are shown in Table 2. Lipid content of BFT body parts shows great variance. The lipid content ranged from 16 to 84 % depending on the sampling parts of the body. The lowest lipid was determined in cheek meat, followed by head meat with a level of 17.7 %. Ordinary dorsal muscle and caudal meat had similar lipid contents around 19.9 and 20.3 % respectively. However, kama meat had double amount of lipid than compared to ordinary muscle (Tab. 1). As a fatty organ, tuna liver contained significant amount of lipid with a level of almost 63 %. Fattened BFT deposit some of the fat in abdominal cavity. Viscera had the highest lipid content in fattened BFT with a level of 84 %.

Moisture content of fattened BFT ranged in between 36 (in kama meat) to 66 % (cheek meat). The present results demonstrated that, the moisture content of ordinary muscle, head and caudal meat were similar, whereas cheek meat and kama meat moisture contents were significantly different from each other ($p<0.05$). Ash contents of different parts of the fattened BFT varied from 0.71 to 1.23 % (Tab. 1). Minimum ash content was present in kama meat, whereas maximum level was found in ordinary muscle. However, wild BFT ordinary muscle had greater level of moisture and ash and lower lipid than fattened BFT dorsal ordinary muscle.

TABLE 1: *Proximate composition of Bluefin Tuna.*

Body part	Moisture	Ash	Lipid
Ordinary muscle	$61.1^{a} \pm 1.1$	$1.23^{a} \pm 0.03$	$20.3^{a} \pm 1.3$
Caudal meat	$60.1^{a} \pm 1.8$	$0.73^{bc} \pm 0.09$	$19.9^{a} \pm 0.5$
Head meat	$61.0^{a} \pm 1.3$	$0.98^{b} \pm 0.07$	$17.8^{b} \pm 0.9$
Cheek meat	$66.4^{b} \pm 2.7$	$0.86^{bc} \pm 0.06$	$16.0^{c} \pm 0.3$
Kama meat	$39.2^{c} \pm 0.7$	$0.71^{c} \pm 0.03$	$43.7^{d} \pm 1.2$
Liver	–	–	$62.9^{e} \pm 0.7$
Viscera	–	–	$84.0^{f} \pm 1.2$
Wild OM[1]	$68.9^{d} \pm 1.1$	$1.84^{d} \pm 0.1$	$12.5^{d} \pm 2.8$

Values are expressed as mean ± standard deviation (N = 3), values in the same column with different superscripts are significantly different ($P < 0.05$). [1]: Wild BFT ordinary muscle compared only with fattened BFT ordinary muscle

Fatty acids profile

The fatty acid composition of various parts of fattened BFT is presented in Table 2. Total 27 fatty acids were identified, major fatty acids were 14:0, 16:0, 16:1n7, 18.0, 18:1n9 and 18:1n7, 18:4n3, 20:1n9, 20:5n3, 22:1n11, 22:5n3 and 22:6n3 Predominant saturated fatty acids (SFA) were 16:0, 18:0, and 14:0 respectively. Total monounsaturated fatty acids (MUFA) were shared between 29–31.7 % of total fatty acids. Among the MUFA's, Oleic acid (18:1n9) was predominant this followed by 16:1n7, 18:1n7, 22:1n11, 20:1n9 in all part that investigated.

Considering the total fatty acids, Poly unsaturated fatty acids (PUFAs) were the major fatty acids in all parts of the fattened BFT, and changed in between 34 to 41 % of the total content (Tab. 2). However, abundance of PUFAs varied within body parts. Head, cheek and liver contained noticeable amounts of PUFA and followed by kama, viscera, caudal and ordinary muscle in decreasing order. DHA and EPA were among the dominant fatty acids. Linoleic acid level in various parts of the fattened BFT ranged from 1.24 to 1.46 %. Similarly, arachidonic acid level was 1.09 % in viscera oil and 1.31 % in liver oil (Tab. 2). Total SFAs, MUFAs and PUFAs levels of menhaden and mackerel were given in Table 3. Total SFAs levels were 32–34 %, MUFAs 20–25 %, PUFAs level 45–40 % in menhaden and mackerel respectively. Both menhaden and mackerel contained a greater amount of n3 PUFAs than n6 PUFAs.

Total SFA, MUFA and PUFA levels were 33.6, 31.38, and 35.46 % in wild BFT, respectively. Ratio of DHA to EPA was 5.03 and n3:n6 ratio was nearly 7.49 levels in wild BFT (Tab. 4) whereas these ratios were 1.02 and 10.86 in fattened BFT.

TABLE 2: *Fatty acid distribution in various organs of fattened Bluefin tuna (Percentage area of FA).*

Fatty acid	Ord. muscle	Caudal meat	Head meat	Cheek Meat	Kama meat	Liver	Viscera
C14:0	$6.14^{d} \pm 0.55$	$5.86^{cd} \pm 0.33$	$5.67^{abcd} \pm 0.27$	$5.29^{ab} \pm 0.22$	$5.59^{abc} \pm 0.21$	$5.74^{bcd} \pm 0.37$	$5.18^{a} \pm 0.10$
C15:0	$0.63^{ab} \pm 0.16$	$0.65^{b} \pm 0.02$	ND	$0.58^{ab} \pm 0.09$	$0.52^{a} \pm 0.03$	$0.58^{ab} \pm 0.02$	$0.53^{ab} \pm 0.05$
C16:0	$19.45^{b} \pm 1.55$	$18.17^{ab} \pm 0.4$	$18.8^{ab} \pm 1.4$	$17.57^{a} \pm 1.58$	$17.81^{ab} \pm 1.03$	$16.9^{a} \pm 0.25$	$18.56^{ab} \pm 0.9$
C17:0	$0.75^{ab} \pm 0.17$	$0.77^{b} \pm 0.05$	ND	$0.65^{ab} \pm 0.14$	$0.61^{a} \pm 0.04$	$0.69^{ab} \pm 0.05$	$0.61^{a} \pm 0.04$
C18:0	$6.40^{c} \pm 0.44$	$5.95^{bc} \pm 0.16$	$5.86^{bc} \pm 0.12$	$5.23^{a} \pm 0.88$	$5.57^{ab} \pm 0.21$	$5.94^{bc} \pm 0.08$	$5.13^{a} \pm 0.06$
C20:0	$0.61^{a} \pm 0.11$	$0.63^{a} \pm 0.02$	$0.50^{a} \pm 0.38$	$0.54^{a} \pm 0.19$	$0.52^{a} \pm 0.05$	$0.56^{a} \pm 0.01$	$0.54^{a} \pm 0.05$
∑ SFAs	$33.97^{a} \pm 2.98$	$32.04^{ab} \pm 0.96$	$30.81^{b} \pm 2.06$	$29.85^{b} \pm 3.1$	$30.63^{b} \pm 1.58$	$30.44^{b} \pm 0.78$	$30.56^{b} \pm 1.22$
C16:1 n-7	$8.04^{c} \pm 0.30$	$8.03^{c} \pm 0.05$	$7.71^{ab} \pm 0.23$	$7.46^{a} \pm 0.19$	$7.88^{bc} \pm 0.20$	$7.73^{ab} \pm 0.09$	$7.53^{a} \pm 0.18$
C17:1 n-10	ND	$0.56^{a} \pm 0.01$	ND	ND	ND	$0.45^{b} \pm 0.04$	ND
C18:1 n-9	$13.81^{bc} \pm 1.1$	$12.8^{bc} \pm 0.10$	$12.3^{ab} \pm 0.43$	$13.22^{abc} \pm 1.08$	$13.86^{bc} \pm 0.55$	$11.58^{a} \pm 0.23$	$14.21^{c} \pm 0.60$
C18:1 n-7	$4.02^{b} \pm 0.04$	$3.87^{ab} \pm 0.04$	$3.78^{a} \pm 0.23$	$3.69^{a} \pm 0.21$	$3.86^{ab} \pm 0.12$	$3.77^{a} \pm 0.05$	$3.86^{ab} \pm 0.02$
C20:1 n-9	$2.67^{ab} \pm 0.36$	$3.11^{b} \pm 0.08$	$2.64^{ab} \pm 0.23$	$2.34^{a} \pm 0.60$	$2.66^{ab} \pm 0.77$	$2.90^{ab} \pm 0.04$	$2.90^{ab} \pm 0.47$
C22:1 n-11	$3.11^{c} \pm 0.45$	$3.20^{c} \pm 0.33$	$3.33^{c} \pm 0.58$	$2.30^{a} \pm 0.47$	$2.44^{ab} \pm 0.29$	$2.93^{bc} \pm 0.39$	$3.21^{c} \pm 0.17$
∑ MUFAs	$31.64^{a} \pm 2.22$	$31.6^{a} \pm 0.61$	$29.77^{a} \pm 1.70$	$29.00^{a} \pm 2.56$	$30.70^{a} \pm 1.93$	$29.37^{a} \pm 0.85$	$31.71^{a} \pm 1.44$
C16:2 n-4	$0.72^{a} \pm 0.11$	$0.76^{a} \pm 0.68$	$0.63^{a} \pm 0.54$	$0.69^{a} \pm 0.11$	$0.77^{a} \pm 0.11$	$0.86^{a} \pm 0.05$	$0.62^{a} \pm 0.05$
C16:3 n-4	$0.58^{ab} \pm 0.26$	$0.71^{ab} \pm 0.03$	$0.53^{a} \pm 0.12$	$0.58^{ab} \pm 0.28$	$0.66^{ab} \pm 0.28$	$0.86^{b} \pm 0.01$	$0.51^{a} \pm 0.22$
C16:4 n-1	$0.91^{a} \pm 0.18$	$1.03^{ab} \pm 0.02$	$1.01^{ab} \pm 0.08$	$0.99^{ab} \pm 0.20$	$1.17^{b} \pm 0.12$	$1.35^{c} \pm 0.01$	$0.89^{a} \pm 0.08$
C18:2 n-6	$1.39^{ab} \pm 0.16$	$1.46^{b} \pm 0.02$	$1.30^{ab} \pm 0.13$	$1.41^{ab} \pm 0.17$	$1.32^{ab} \pm 0.12$	$1.39^{ab} \pm 0.02$	$1.24^{a} \pm 0.02$
C20:2 n-6	ND	$0.39^{b} \pm 0.02$	ND	$0.19^{ab} \pm 0.22$	$0.39^{b} \pm 0.29$	$0.36^{b} \pm 0.09$	ND
C20:3 n-6	ND	ND	ND	$0.12^{a} \pm 0.13$	ND	$0.24^{a} \pm 0.22$	ND
C20:4 n-6	$1.18^{ab} \pm 0.15$	$1.22^{ab} \pm 0.14$	$1.25^{ab} \pm 0.23$	$1.31^{b} \pm 0.04$	$1.13^{ab} \pm 0.07$	$1.31^{b} \pm 0.08$	$1.09^{a} \pm 0.05$
C22:4 n-6	$0.39^{a} \pm 0.81$	$0.69^{a} \pm 0.01$	ND	$0.77^{a} \pm 0.03$	$0.74^{a} \pm 0.05$	$0.84^{a} \pm 0.03$	$0.71^{a} \pm 0.01$
C22:5 n-6	ND	$0.41^{a} \pm 0.03$	ND	ND	ND	$0.39^{a} \pm 0.07$	ND
∑ n6	$2.95^{ab} \pm 1.12$	$4.16^{cd} \pm 0.23$	$2.55^{a} \pm 0.37$	$3.80^{bcd} \pm 0.44$	$3.58^{bc} \pm 0.47$	$4.53^{d} \pm 0.49$	$3.04^{ab} \pm 0.09$
C18:3 n-3	$0.85^{a} \pm 0.25$	$0.88^{a} \pm 0.04$	$0.91^{a} \pm 0.05$	$0.90^{a} \pm 0.15$	$0.82^{a} \pm 0.05$	$0.91^{a} \pm 0.02$	$0.80^{a} \pm 0.03$
C18:4 n-3	$2.09^{a} \pm 0.21$	$2.28^{ab} \pm 0.13$	$2.46^{bc} \pm 0.12$	$2.42^{bc} \pm 0.37$	$2.39^{abc} \pm 0.20$	$2.67^{c} \pm 0.03$	$2.21^{ab} \pm 0.09$
C20:4 n-3	$0.96^{a} \pm 0.40$	$0.94^{a} \pm 0.11$	$1.30^{a} \pm 0.54$	$1.04^{a} \pm 0.04$	$0.95^{a} \pm 0.09$	$1.06^{a} \pm 0.11$	$0.94^{a} \pm 0.13$
C20:5 n-3	$11.27^{a} \pm 0.95$	$10.89^{a} \pm 0.14$	$13.68^{b} \pm 0.38$	$13.08^{b} \pm 1.93$	$13.37^{b} \pm 0.32$	$12.96^{b} \pm 0.07$	$12.61^{b} \pm 0.50$
C22:5 n-3	$2.22^{a} \pm 0.12$	$2.37^{ab} \pm 0.07$	$2.51^{bc} \pm 0.10$	$2.68^{c} \pm 0.23$	$2.49^{bc} \pm 0.04$	$2.49^{bc} \pm 0.08$	$2.49^{bc} \pm 0.17$
C22:6 n-3	$11.74^{a} \pm 0.11$	$12.5^{ab} \pm 0.19$	$14.41^{cd} \pm 0.56$	$15.00^{d} \pm 2.23$	$12.67^{ab} \pm 0.05$	$12.13^{ab} \pm 0.26$	$13.22^{bc} \pm 0.23$
∑ n3	$29.14^{a} \pm 2.04$	$29.87^{a} \pm 0.68$	$35.27^{b} \pm 1.75$	$35.11^{b} \pm 4.95$	$32.69^{ab} \pm 0.74$	$32.21^{ab} \pm 0.57$	$32.27^{ab} \pm 1.16$
∑ PUFAs	$34.29^{a} \pm 3.71$	$36.52^{ab} \pm 1.55$	$40.0^{b} \pm 2.73$	$41.16^{b} \pm 5.81$	$38.86^{ab} \pm 1.68$	$39.83^{b} \pm 1.12$	$37.32^{ab} \pm 1.6$
n3:n6	$10.90^{b} \pm 3.70$	$7.20^{a} \pm 0.24$	$13.97^{c} \pm 1.35$	$9.27^{ab} \pm 1.10$	$9.\ 24^{ab} \pm 1.04$	$7.16^{a} \pm 0.62$	$10.61^{b} \pm 0.06$
DHA:EPA	$1.05^{b} \pm 0.08$	$1.15^{c} \pm 0.00$	$1.05^{b} \pm 0.01$	$1.15^{c} \pm 0.01$	$0.95^{a} \pm 0.02$	$0.94^{a} \pm 0.02$	$1.05^{b} \pm 0.02$

Values are expressed as mean ± standard deviation (N = 3), values in the same row with different superscripts are significantly different ($P < 0.05$). Ord. muscle: Ordinary muscle

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Discussion

Proximate composition

In general, any fish having more than 10 % lipid in their muscle, considered to be as a fatty fish. Therefore, even the lowest lipid containing part of the fattened BFT lays in fatty fish category. Lipid in the fish muscle is not distributed evenly throughout the flesh and among the fish species (Kaneko, et al., 2016).

The sum of moisture and lipid content of BFT muscle was nearly constant at about 80 %. Low level of moisture content was calculated in high lipid containing body parts. Lipid content of ordinary muscles of the wild and fattened BFT were 12.6 and 20.3 %, and moisture contents were 68.9 and 61.6 % respectively. The wild BFT ordinary muscle had significantly lower lipid ($p<0.05$) and higher moisture content than the fattened BFT ordinary muscle. In wild, fish solely depend on available food in their habitat and has to make a great effort to obtain it. Therefore, all these effort and limited food sources may lower the wild BFT lipid content in their muscle. In contrast to wild BFT, fattened BFT ordinary muscle lipid content was significantly higher than its counterpart ($p<0.05$). In fattening process, the fish were fed with fatty pelagic fish *ad libitum* at least twice a day to gain weight. In turn, fattened fish accumulated more lipids in their muscle compared to the wild BFT. The lipid content of different part of the body makes great difference for market and consumer due to its size and weight.

Ash content is the least fluctuating component of fish muscle. Regardless of marine or freshwater fish muscle contains about 1–2 % ash. However, fish muscle with a small pin bone may have more ash level than ordinary flesh. The ash content of fattened BFT was in the range of 0.86–1.23 %, depending upon where the sample was taken from. The ash content of wild BFT ordinary muscle was 1.84 % level and significantly higher ($p<0.05$) than fattened BFT ordinary muscle. Present results in ash contents agree with the study on BFT in Antalya Gulf (Yerlikaya et al., 2009).

Higher level of ash was reported in wild Pacific tuna *(Thunnus orientalis)* than its cultured specimen (Roy et al., 2010). Findings prove that the wild BFT may contain more minerals than the fattened BFT, due to its high ash content.

The proximate composition of fish may be affected by factors such as water temperature, season, spawning, and migration, feeding habits and availability of the food in the habitat. A significant change in lipid content of full cycled Pacific tuna *(Thunnus orientalis)* was reported and these changes occurred from 11 to 23 % from April to May, and decreases in moisture content from 67.9 to 55 % (Nakamura et al., 2007a). The lipid content of the fattened BFT in the Mediterranean increased significantly from 3.25 to 16.55 % from start the fattening to harvesting. In contrast to lipid content, moisture level decreased from 80.5 to 60 % in the same period (Yerlikaya et al., 2009).

Depending on growing conditions, wild fish contains lower lipid than farmed counterpart (Sérot et al., 1998). In general, fish liver accumulates more lipid than ordinary muscle. Previous studies acknowledged that wild Atlantic BFT during reproductive migration, stored more lipids in liver (8.8–14.2 %) than ordinary muscle (Sprague et al., 2012) and much greater amount was present in adipose tissue. In comparison, the former lipid content in the liver with current findings (62 %), it seems the wild Atlantic BFT's liver contained less than the fattened BFT. This phenomenon could be explained by the spawning migration of the Atlantic bluefin tuna in south west coast of Spain. Spawning migration may cause a depletion of lipid in liver. And fattening process may help to accumulate excess lipid in liver. The liver lipid content of fish may vary by season, spawning condition, migration and availability of food in the wild. However, these factors occur lesser extend in fattening process of tuna due to their limited swimming activities, and also for the better feeding conditions than the wild. As a consequence, more lipid accumulation in muscle and liver are expected in the fattened BFT.

Fatty acid distribution

The fatty acid profile of the fattened BFT was predominated by PUFAs which comprised nearly 34 to 40 % of the total fatty acids and followed by SFAs and MUFAs. The SFAs accounted for nearly 1/3 of the total fatty acids. These SFAs in BFT muscle, reported by some researchers in the same order as current findings with different levels (Chantachum et al., 2000; Popovic et al., 2012; Sprague et al., 2012). Total SFAs in different part of the BFT varied significantly from 11.5 to 13.9 %. Distribution of SFAs in different parts of the body varied, and the lowest SFAs were calculated in the viscera and the highest was present in the head meat.

However, MUFAs level was similar in all parts of the body. Oleic acid was the major MUFAs in fattened BFT as present in most marine fish species. Oleic acid content of the wild BFT was much lower than the fattened BFT. Among the MUFAs 22:1 fatty acid was the distinctive fatty acid in the fattened BFT which was not found in the wild BFT. Initially, 22:1 fatty acid was identified as an erucic acid (22:1n9), later it was re-identified by adding internal standard of 22:1n9 fatty acid methyl ester and identified with GC-MS. The fatty acid chromatogram of the internal standard added sample indicated that, targeted peak eluted earlier than internal standard of 22:1n9 fatty acid. Therefore, the targeted peak was determined as cetoleic acid (22:1n11). Cetoleic acid was present from 2.3 to 3.3 % of the total fatty acids in fattened BFT, and this fatty acid may be seen as an indicator fatty acid to distinguish fattened BFT from its wild counterpart, due to the absence of this particular fatty acid in the wild BFT captured in the north east Mediterranean. However, the presence of 22:1n11 fatty acid was reported in the wild BFT caught in Barbate Coast (Spain) in May (Popovic et al., 2012); and great variance was stated in its level between years, location and tuna species (Mourente et al., 2015; Parrish et al., 2015).

PUFAs are one of the chief interests of nutritionists, because of their positive effect on human health. Many papers have been published about the benefits of DHA and EPA on cardiovascular and neural diseases. Omega 3 fatty acids are crucial for normal development of the brain and retinal tissues and for the maintenance of normal neurotransmission and connectivity (Assisi et al., 2006). Regular access to shore based diet and the ability to store DHA in foetal body fat contributed significantly to development of human brain (Wenstrom, 2014).

Considering the abundance of DHA content in body parts as follows in decreasing order: cheek meat>head meat>viscera>kama meat>caudal meat> liver. Evidence suggests that DHA intake in pregnancy provides advantages for mother and foetus development (Saldanha et al., 2009). Clinical trials suggest that supplemental algal DHA

TABLE 3: *Fatty acid profiles (%) of fish used for feeding fattened BFT.*

Body part	Menhaden	Mackerel*
∑ SFAs	32.36 ± 0.85	34.59 ± 0.41
∑ MUFAs	20.52 ± 0.33	25.04 ± 2.95
∑ PUFAs	45.22 ± 1.28	40.37 ± 3.36
∑ n6 PUFAs	3.34 ± 0.46	4.02 ± 0.02
∑ n3 PUFAs	36.14 ± 1.05	36.35 ± 3.34
DHA:EPA	1.19	2.45

*: Adopted from (Lim, 2012)

has moderate beneficial effects on blood pressures and resting heart rates, risk factor for cardio vascular diseases (Holub, 2009). Therefore, the consumption of fattened BFT, that have high level of lipid in their edible tissue from (16 to 43%), and having considerable amounts of DHA and EPA, may be recommended preventing cardio vascular health problems.

In comparison, total n3 levels were much greater than total n6 levels in all parts of the fattened BFT. The highest n3:n6 ratio was found in the head meat, ordinary muscle, viscera and cheek meat respectively. In many farmed fish n3:n6 ratio in muscle is negatively altered by having high level of linoleic acid which is present in their commercial diet (Öksüz, 2012). In fattening process of the BFT, so far commercial fish diet for BFT has not been put in practice yet, in most cases frozen pelagic fish are used as feed. Therefore, fattened BFT's fatty acid profile differs from the other aqua-cultured fish species in terms of n3:n6 ratio and the linoleic acid content. Recommended n3:n6 ratio of 1:6 is considered to be adequate for nutritional needs for most healthy adults, and this ratio differs from 1:4 to 1:7.5 (Gebauer et al., 2006) depending on the countries.

There are some similarities in fatty acid profiles of the fish used for the fattening BFT (Tab. 3). Total SFAs in fattened and the wild BFT were similar, in particular dorsal ordinary muscle. However, MUFA level in BFT was much greater than of the fish used as feed. Total PUFAs in cheek and head meat was similar with the feed, but much lower than the other parts of BFT. Total n3 fatty acids level in the fish was similar in the other parts of the body, except ordinary muscle and caudal meat which have slightly lower level PUFAs than others. Apart from caudal meat and liver, the ratio of n3:n6 in fattened BFT was similar to their feed n3:n6 ratio (Tab. 4). The wild BFT differs from the fattened BFT, having higher level of 22:6n3 fatty acid. Among the SFAs; C14:0, C17:0, C18:0 were significantly different in the wild BFT from the fattened BFT (Tab. 4). Oleic acid was the major MUFAs in both the wild and the fattened BFT. However, oleic acid content was much higher in the wild than the fattened BFT. Similar result was reported by Popovic et al., (2012). In contrast to oleic acid, 20:1n9 fatty acid was greater in the fattened BFT than its wild counterpart. ARA (20:4n6) was almost double in the wild BFT, contributing about 2.4 % of total fatty acid. High level of ARA is not desirable due to its negative nutritional effect.

The migratory fish species are rich in DHA, and the quantity of this is not affected by maturity (Nakamura et al., 2007b). However, when DHA levels of the wild and the fattened BFT are compared, it is obvious that DHA level was negatively affected from the fattening process vice versa to EPA level. DHA was the most noticeable fatty acid in the wild BFT, and it contains twice as much of DHA than the fattened BFT. In contrast to DHA, EPA level of the wild BFT was much lower than the fattened BFT. Similarly, high level of DHA content was reported in wild Albacore tuna compare to EPA level (Rasmussen et al., 2008). Both EPA and DHA belong to omega 3 fatty acid series, and they are nutritionally important. However, both fatty acids fulfill the body requirements in different manner. DHA and EPA have both important haemodynamic and anti-atherogenic properties, although they show independent effects on cardiovascular risk factors in humans (Tenore et al., 2014). There were no significant differences between the wild and the fattened BFT, in terms of total SFAs, MUFAs and PUFAs, but DHA: EPA ratio greatly differed in the wild and the fattened BFT, having the value of 5.03 and 1.02 respectively. ARA level (2.4 %) was much higher in the wild than the fattened BFT (1.17 %).

TABLE 4: *Fatty acid profile of wild versus to fattened BFT ordinary muscles (Percentage area of FA).*

Fatty acids	WBFT	FBFT
C14:0	2.87ᵃ ± 0.11	6.14ᵇ ± 0.56
C15:0	0.95ᵃ ± 0.10	0.51ᵃ ± 0.36
C16:0	21.32ᵃ ± 1.27	19.31ᵃ ± 1.8
C17:0	1.30ᵃ ± 0.03	0.61ᵇ ± 0.42
C18:0	7.50ᵃ ± 0.12	6.36ᵇ ± 0.52
C20:0	0.23ᵃ ± 0.40	0.63ᵃ ± 0.08
∑ SFAs	33.78ᵃ ± 0.51	33.57ᵃ ± 3.63
C16:1n-7	4.01ᵃ ± 0.43	7.98ᵇ ± 0.41
C17:1 n-10	0.72 ± 0.02	ND
C18:1 n-9	20.77ᵃ ± 0.30	13.60ᵇ ± 1.40
C18:1 n-7	3.96ᵃ ± 0.06	3.90ᵃ ± 0.27
C20:1 n-9	1.91ᵃ ± 0.03	2.70ᵇ ± 0.32
C22:1 n-11	ND	3.13 ± 0.42
∑ MUFAs	31.38ᵃ ± 0.59	31.31ᵃ ± 2.81
C16:2 n-4	0.83ᵃ ± 0.30	0.70ᵃ ± 0.15
C16:3 n-4	ND	0.61 ± 0.23
C16:4 n-1	ND	0.96 ± 0.11
C18:2 n6	1.50ᵃ ± 0.08	1.38ᵃ ± 0.17
C20:2 n-6	0.20 ± 0.17	ND
C20:3 n-6	0.21 ± 0.19	ND
C20:4 n-6	2.40ᵃ ± 0.11	1.17ᵇ ± 0.16
C22:4 n-6	0.31ᵃ ± 0.27	0.51ᵃ ± 0.65
C22:5 n-6	1.06 ± 0.92	ND
∑ n6	4.19ᵃ ± 0.86	3.06 ᵃ ± 0.97
C18:3 n-3	0.77ᵃ ± 0.15	0.93ᵃ ± 0.15
C18:4 n-3	0.79ᵃ ± 0.17	2.21ᵇ ± 0.15
C20:4 n-3	0.14ᵃ ± 0.29	1.01ᵇ ± 0.33
C20:5 n-3	4.55ᵃ ± 0.21	12.02ᵇ ± 1.03
C22:5 n-3	1.90ᵃ ± 0.33	2.30ᵃ ± 0.10
C22:6 n-3	22.29ᵃ ± 1.10	12.27ᵇ ± 0.98
∑ n3	30.24ᵃ ± 0.97	30.75ᵃ ± 2.11
∑ PUFAs	35.46ᵃ ± 3.64	36.07ᵃ ± 4.22
n3:n6	7.49ᵃ ± 1.73	10.86ᵃ ± 3.62
DHA:EPA	5.03ᵃ ± 0.09	1.02ᵇ ± 0.05

Values are expressed as mean ± standard deviation (N = 3), values in the same row with different superscripts are significantly different (P < 0.05).

The high intake of oil rich seafood, such as tuna, provides PUFAs which human body may not synthesize in sufficient level to support optimal health. Strong recommendation of fish consumption is not only they provide PUFAs but also supply essential macro and micro nutrients (Lund, 2013).

Conclusion

Bluefin tuna lipid content is positively influenced by the fattening process. Distribution of lipid in tuna body was not uniform and was in the range of 16–44 % in the whole body. Dorsal muscle represents almost the average lipid content of total edible muscle of BFT. Lipid content of different body part of BFT may provide guidance to the processor in order to utilize them efficiently. High level of 22:1n11 fatty acid along with DHA:EPA ratio in BFT may be used to differentiate the fattened from the wild BFT. By product of BFT such as liver and viscera may be utilized as lipid sources to obtain rich omega 3 fatty acids.

Tuna meat is also rich in protein and can easily be digested due to low quantity of connective tissue. Instead of consuming fish oil or capsule alone, it is better to consume oil rich seafood to receive the adequate amount of protein and other essential nutrients.

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Conflict of interest

The author declare no conflict of interest.

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