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The influence of feeding on muscle tissues composition in cage reared bluefin tuna (*Thunnus thynnus*)

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*Capture-based tuna aquaculture rates as one of the most important aquaculture activities in Croatia, where juvenile tuna are reared in cages for over a year long period in order to increase substantially their weight. The aim of this study was to assess the effect of length and intensity of feeding on biochemical composition (total fat, moisture, dry matter, carbohydrates and protein content) of tuna (*Thunnus thynnus*) white muscle tissues in newly caught tuna prior to feeding (NCTPF) versus farmed tuna kept in rearing circular cages in the Vela Grska Bay, Adriatic Sea (LAT 43°17'40,6984"N, LONG 016°28'58,4315"E (WGS84)) between 2001 and 2004. Farmed tunas from all cages were fed with the feed consisting of domestic small pelagic fish, or with mixtures containing North Sea herring (Clupea harengus) and Sardina pilchardus, for five months (cage 3), eight months (cage 4) or 21 months (cages 1 and 2). A low content of moisture and high content of dry matter including fat was observed in farmed tuna muscles compared to wild-caught tuna. In farmed tuna muscles, measured moisture was 55.26% in cage 1, 39.95% in cage 2, 54.64% in cage 3 and 49.70% in cage 4. These results are significantly lower than moisture measured in NCTPF (80.36%). Content of dry matter found in farmed tuna muscles also differed greatly between wild tuna (19.64%) and farmed tuna, but also between the cages (44.74% in cage 1, 60.05% in cage 2, 45.36% in cage 3 and 50.30% in cage 4). In NCTPF, muscle tissues total fat encompassed less than 1% of the total body weight, while it reached over 20% of total body mass in farmed fed tuna (20.62% in cage 1, 42.50% in cage 2, 20.97% in cage 3 and 20.57% in cage 4). These results demonstrate that high fat content can be achieved already after five months of intensive feeding. Higher content of proteins was also found in aquacultured tuna (18.60% in cage 1, 16.00% in cage 2, 15.09% in cage 3 and 20.58% in cage 4) compared to wild-caught tuna (13.77%). There were no differences in carbohydrates content between tuna farmed in different cages and NCTPF tuna, indicating glycogen as a less optimal indicator of muscle tissue quality in farmed tuna of the present study.*

Key words: bluefin tuna, feeding, muscle tissue composition, cage rearing, the Grška Bay

INTRODUCTION

Since the first attempts of tuna (*Thunnus thynnus*) capture-based aquaculture, its fattening and rearing technology has continued to develop, as the species continued to have a global economic importance based on the high market demand and high price, mostly due to the desirable biochemical composition of its meat (BIMOL *et al*., 2010). In the late 1960s, Japan started the first tuna rearing activities in Canadian waters by keeping fish in cages for several months. Fish gained in mass and fat content during the feeding period, so that even medium size tuna could be sold in the Japanese market for a relatively good price, providing it had a high fat content and pink meat color. In 1996, fishermen returning to Croatia from Australia, started tuna rearing by applying their Australian experience (KATAVIĆ *et al*., 2003). Since then, the production sharply increased, resulting in 2,162 tons produced in 2017, with the ICCAT (International Commission for the Conservation of Atlantic Tunas) quota set at 779.84 tons for 2018 (GRUBIŠIĆ*, personal communication*). However, the difference in Mediterranean and Croatian tuna aquaculture is that in the former, adult tuna over 30 kg are caught therefore the fattening period lasts for six to ten months, in contrast to Croatia, where mostly juvenile tuna of 8 to 12 kg are caught and the rearing period lasts 1.5 years or more.

Although having a relatively long capture-based aquaculture history, according to MOURENTE & TOCHER (2009) little is known about the quantitative or qualitative nutritional requirements of large Thunnini. The body composition of wild tuna may indicate possible dietary requirements, at least in respect to the fat content and fatty acid composition. Therefore, the investigation of the feeding effect on the biochemical composition of farmed fish has lately been intensified. SORIGUER *et al.* (1997) observed significant variations in the total fat, protein and fatty acid content in baitfish used for tuna feeding. GLENCROSS *et al.* (2007) highlighted that the evaluation of feed ingredients is crucial to nutritional research and feed development for aquaculture species. Likewise, MLADINEO *et al.* (2006) reported a devastating outbreak of pasteurelosis in farmed tuna, related to long-term misbalanced feeding with poor-quality baitfish. Furthermore, the fact that meat fat levels can vary so widely has important consequences for farming. Generally, consumers assume that farmed fish are poor in quality and flavor compared to their wild counterparts (HAARD, 1992; RASMUSSEN, 2001; TOMIĆ *et al.*, 2017). Indeed, some authors suggest (FARNDALE *et al.,* 1999; HEMRE & SANDNES, 1999; SKOG *et al.,* 2003) that wild fish tend to be leaner and firmer than the latter, attributing this to a high fat content in cultured fish (RASMUSSEN, 2001; FLOS *et al*., 2002; GRIGORAKIS *et al.*, 2002). Differences between wild fish and their cultured counterparts have been observed in a variety of fish species (GRIGORAKIS *et al.,* 2002; ORBAN *et al.,* 2003), but unlike in other cultured fish, high fat content in aquaculture tuna is highly prized in the sushi and sashimi Japanese market, although its quantitative and qualitative profiles are not always the only reliable indicators of fish value. The aim of this study was to assess the effect of length and intensity of feeding on the biochemical composition (total fat, moisture, dry matter, carbohydrates and protein content) of tuna white muscle tissues in wild non-fed tuna and aquacultured tuna kept in rearing circular cages in the Grška Bay (LAT 43°17’40,6984”N, LONG 016°28’58,4315”E (WGS84)) between 2001 and 2004.

MATERIAL AND METHODS

Experimental design

Tuna (*Thunnus thynnus*) was farmed in four circular cages (60 m in diameter and 25 m deep) in the Grška Bay, Adriatic Sea (LAT 43°17’40,6984”N, LONG 016°28’58,4315”E (WGS84)) from summer 2001 till winter 2004. Tuna had been caught SW of the Island of Jabuka, the Adriatic Sea, using purse seine nets. Wild caught individuals differed in biomass (Table 1).

During the farming period, sea temperature (ºC) and oxygen saturation (%) were measured at the sea surface and at 15 m depth, three times a day, every day. The measurements were

Table 1. The weight categories (kg) and number of individuals, total weight (kg) and density (kg/m³) of tuna in the cages at the beginning and at the end of feeding process

CAGE	REARED TUNA							
	At the beginning of the feeding process				At the end of the feeding process			
	Weight categories of indiv. (kg)	No. of indiv.	Total mass (kg)	Density (kg/m³)	Weight categories (kg)	No. of indiv.	Total weight (kg)	Density (kg/m³)
1	3.5	7183	25919	0.73	27	5314	142404	4.03
2	3.5	6743	23562	0.36	27	3236	110913	1.72
3	11.0	713	7854		29	265	7641	
	17.0	265	4505		31	671	20801	
	30.0	524	15720		56.5	514	29052	
	total	1502	28079	1.06		1450	57494	2.04
4	11.0	5137	56507		27	4964	133457	
	20.0	80	1600		51	77	3940	
	total	5217	58107	1.41		5041	137398	3.33

made between 07:00 and 08:00 in the morning, between 13:00 and 14:00 in the afternoon and between 18:00 and 19:00 in the evening, using Sinergia WTR portable oximeter.

Tuna was fed with domestic small pelagic fish (DSPF – pilchard (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and mackerel (*Scomber scombrus*) depending on seasonal availability, and a mixture of imported herrings (*Clupea harengus*) and pilchard (*Sardina pilchardus*) from the North Sea. Herring and pilchard were kept in frozen blocks (30 kg) at -20 °C and defrosted in a defrosting plant using sea water. Defrosted fish were kept in plastic containers (800 kg) and transported to the vessels for feeding.

In cage 1, the tuna formed weight category (NFTPF) 3.5 kg and tuna were farmed for 21 months (552 days; from May 2001 till January 2003). Cage 1 was located in the Mala Maslinova Bay and relocated to the Grška Vela Bay in May 2002. In 2001, the tuna were fed *ad libitum* one to two times a day (at 11.00 am and 3.00 pm), six times a week. Divers observed the feeding at different depths in order to evaluate the efficiency of the process. In March 2002, the intensity of feeding first increased at three to four times a day and afterwards at five to six times a day, seven days a week, from 07.00 am to 07.00 pm, *ad libitum*. The feeding process was stopped only in case of extremely bad weather conditions.

In cage 2, the tuna formed weight category (NFTPF) 3.5 kg and the tuna were fed for 21 months (547 days; from April 2002 till January 2004). During the whole feeding period, in the cages 2, 3 and 4 the intensity of feeding was higher than in cages 1; ad *libitum*, five to six times a day, seven days a week, from 07.00 am to 07.00 pm.

In cage 3, 713 individuals were formed weight category 11 kg, 265 individuals were fromed weight category 17 kg and 514 individuals were formed weight category 30 kg. The tuna fed for five months (155 days; from August 2003 till January 2004). In cage 4, 5132 individuals were formed weight category 11 kg and 80 individuals were form weight category 20 kg. The tuna were fed for eight months 240 days; from May 2003 till January 2004.

Sampling and biochemical analysis

In total, 40 aquacultured tuna (10 individuals per cage) were collected for biochemical tissue composition analysis, as well as 10 NCTPF. The body incisions for muscle sampling are shown in Figure 1.

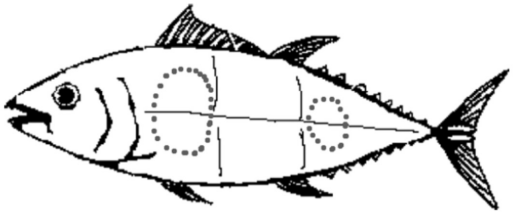

Fig. 1. The position of tuna (T. thynnus) tissue sampling for muscle biochemical composition analysis (after Yoshi-Nori et al., 2007)

The date of sampling, duration of the feeding period, and average body weight of sampled tuna are shown in Table 2. Muscle samples from individual aquaculture tuna and NCTPF tuna were homogenized prior to biochemical analyses of fat, moisture and dry matter, protein and carbohydrate content.

In homogenized samples (3 g), fat content was determined following the Association of Official Analytical Chemists (AOAC) Official method 948.15 Fat (Crude) in Seafood - Acid hydrolysis method, 1995 (Hungerford, 1995) modified by Rasmussen & Morrissey (2007). The content of moisture and dry matter was determined following the Association of Official Analytical Chemists (AOAC) Official method 950.46 B Convection, Gravity method, 1995 (Sodeberg, 1995). For protein and carbohydrate analyses, tissues were homogenized using the Polytron homogenizer in triple volume of cold 35% NaCl. Aliquots for protein (1 ml) and carbohydrate analyses (1 ml) were taken from the homogenized sample. Proteins were extracted by adding 0.5 M NaOH to the aliquot at a 1:5 ratio. After 24 h at 4°C, the sample was mixed, transferred into a polyethylene test tube and centrifuged at 4000 rpm for 15 minutes at 4°C. Protein content was determined by the Bradford method using Bovine Serum Albumin (BSA) as standard (Bradford, 1976). Carbohydrate concentration was obtained following SAUCEDO *et al.* (2002) upon addition of 20% trichloroacetic acid (Merck) on aliquot at a 1:1 ratio.

Statistical analysis

During the farming period, sea temperature (°C) and oxygen saturation (%), quantity of given food (kg), the quantities of different types of food (kg) and the mortality (number of individuals and their weight) were measured. The results were encompassed into two groups: the first group included those from the cage 1 and cage 2, while the second group included those from the cage 3 and cage 4. This was done because the duration of farming period was markedly different between these two groups. The results were analyzed by software platform IBM SPSS version 10.0: *t*-test and Mann-Whitney test were used ($p<0.001$).

Table 2. Muscle sampling for biochemical tissue composition analysis, date, duration of the feeding period, and average body weight of sampled tuna

	Cage No.	Duration of farming (months)	Date of sampling	Average body weight of sampled tuna (kg)
	0*	-	May 2003	25.06±1.633
	1	21	January 2003	32.18±2.681
	2	21	January 2004	26.37±1.759
	3	5	January 2004	38.43±2.066
	4	8	January 2004	29.28±1.814

*0 newly caught tuna prior feeding

RESULTS

Table 3a. gives the duration of farming period (months), number of feeding days number of individuals, fish weight (kg), density of the fish in the cages (kg/m$^{3)}$ at the beginning and at the end of farming period, and monthly mean values, median and min-max for: number of feeding days, the sea temperature (°C), the oxygen saturation (%).Table 3b gives the total quantity of fed food (kg), the quantity of different food types (kg) and mortality (in number of individuals and their weight), as well as the total fed food and percentages of different food types fed to fish, recorded in four cages (DSPF - domestic small pelagic fish).

The fish in the cages 1 and 2 were farmed for 21 months. At the beginning of the farming the total weight of the fish in the cages were 25919 kg (cage 1) and 23562 kg (cage 2) while the density of the fish in the cages were 0.73 *kg/m^3* (cage 1) and 0.36 *kg/m^3* (cage 2). At the end of farming period, the total weight of the fish in the cages were 142404 kg (cage 1) and 110913 kg (cage 2) while the density of the fish in the cages were 4.03 *kg/m^3* (cage 1) and 1.72 *kg/m^3* (cage 2). The total quantity of fed food was: 1933610 kg (50% of herrings, 49 % of DSPF and 1% of mackerel - cage 1) and 2,809,644 kg (33% of herrings, 38% of DSPF, 24% of imported sardine and 5% of mackerel - cage 2).

The fish in the cages 3 and 4 were farmed for five months (cage 3) and eight months (cage 4) respectively. At the beginning of the farming, the total weight of the fish in the cages were 28079 kg (cage 1) and 58107 kg (cage 2), while the density of the fish in the cages were 1.06 kg/m^3 (cage 1) and 1.41 kg/m3 (cage 2). At the end of farming period, the total weight of the fish in the cages were 57,494 kg (cage 1) and 137,397 kg (cage 2), while the density of the fish in the cages were 2.04 kg/m3 (cage 1) and 3.33 kg/m3 (cage 2).

The total quantity of feed fed to fish was: 501,427kg (70% of herrings, 6.8 % of DSPF 20.2% of imported sardine - cage 1) and 1,033,472 kg (33% of herrings, 38% of DSPF, 24% of imported sardine and 5% of mackerel - cage 2).

Table 3a. The duration of farming period (months), number of feeding days number of individuals, fish mass (kg), density of the fish in the cages (kg/m^3) at the beginning and at the end of farming period, and monthly mean values, median and min-max for: number of feeding days, the sea temperature (°C), the oxygen saturation (%).

CAGE	1	2		3	4
Duration. of farming (months)	21	21	-	5	8
No. of feeding days	552	547	-	155	240
No. of indiv. at the beginning	7183	6746	-	1502	5041
Weight at the beginning (kg)	25919	23562	-	28079	58107
Density of the fish at the beginning (kg/m^3)	0.73	0.36	-	1.06	1.41
No. of indiv. at the end	5314	2811	-	1449	5041
Weight at the end (kg)	142404	111852	-	57494	137397
Fish density at the end (kg/m^3)	4.03	1.72	-	2.04	3.33
No of feeding days/month mv±sd (med;min-max)	26.3±7.1 (29; 2-31)	26.2±5.7 (28; 10-31)	0.94*	26±2.5 (26.5; 22-29)	27±3.6 (27; 20-31)
Temperature (°C)/month mv±sd (med;min-max)	18.9±3,9 (18; 13-25)	19.0±4,2 (18; 13-25)	0.881*	18.8±4 (19; 13-24)	19.8±3.8 (20; 13-24)
Oxygen saturation % mv±sd (med;min-max)	86.3±5.8 (85; 75-99)	86.3±6.3 (87; 75-97)	0.98*	90±7.2 (92; 77-97)	88±6.9 (91; 77-97)

**t*-test ($p<0.001$)
(-) no statistical analysis
mv±sd *(med;min-max) - Mean Value ± Standard Deviation (Median; Minimum – Maximum)*

Table 3b. The total mass of added food (kg), the mass of different types of food (kg) and mortality (in number of individuals and in mass) as well as total added food and percentages of different food types added, recorded for four tuna cages

CAGE	1	2		3	4
TOTAL FOOD /MONTH (kg) mv±sd (med;min-max)	88086±60442 (84949; 1572-203492)	133794±68016 (134303; 2608-304518)	0.04**	83571±19307 (90385; 44392-94110)	114830±35619 (123420;59260-159580)
TOTAL FOOD (kg)	1933610	2809644	-	501427	1033472
Herring/month (kg) mv±sd (med;min-max)	45028±72542 (5553; 0-199435)	47169±56408 (26850; 0-162205)	0.463**	61139±30351 (63447; 2151-93549)	61573±59587 (59260; 0-140526)
Herring/TOTAL FOOD (%)	50	33	-	73	54
DSPF/month (kg) mv±sd (med;min-max)	41840±37919 (38400; 1050-97975)	49906±59802 (20150; 0-206821	0.882**	5674±5274 (6087; 0-11608)	7149±7958 (372; 0-19054)
DSPF/TOTAL FOOD (%)	49	38	-	6.8	6
Imported sardine/month (kg) mv±sd (med;min-max)	0	30716±47971 (26023; 0-146815)	0	16757±26705 (0; 0-6017)	46107±49396 (47314; 0-132641)
Imported sardine/TOTAL FOOD (%)	0	24	-	20.2	40
Mackerel/month (kg) mv±sd (med;min-max)	1217,6±4318 (0; 0-16764)	6003±16009 (0; 0-67619)	0.194**	0	0
Mackerel/ TOTAL FOOD (%)	1	5	-	0	0
Food/individual*month (kg) mv±sd (med;min-max)	17±10,5 (15,8; 0,03-38,2)	31,7±14,9 (31,5;3,9-63,4)	0.001**	57±13 (61; 31-64,5)	22,5±7 (24,5; 12-32)
Mortality/month (no of indiv.) mv±sd (med;min-max)	89±201 (5; 0-785)	134±344 (11; 0-1549)	0.226**	8,8±9,6 (5,5; 0-21)	17±17 (8; 0-48)
Mortality/month (kg) mv±sd (med;min-max)	380±773 (68; 0-2964)	919±1803 (151; 0-6695)	0.125**	175±181 (111; 0-413)	226±230 (163; 0-772)

***Mann-Whitney test* ($p<0.001$)
(-) no statistical analysis
DSPF - domestic small pelagic fish;
mv±sd *(med;min-max) - Mean Value ± Standard Deviation (Median; Minimum – Maximum)*

Table 3. indicates statistically significant difference only for feed fed per individual per month ($p<0.001$) for the first group of cages (cages 1 and 2), as well as for feed fed per individual, per month, and for total feed fed per months for the second group of cages (cages 3 and 4).

Table 4. indicates values of fat, moisture, dry matter, protein and carbohydrate content in tuna muscles farmed in four different cages and wild-caught tuna muscles. The table 4. shows that the highest values of moisture as well as the lowest values of dry matter and fat was measured in the sample 0 (newly caught tuna prior feeding), while the highest values of dry matter and fat, as well as the lowest values of moisture, were measured in sample 3 (the fish from cage 2). In June and July 2002, the fish in the cage 2 had high mortality because of the skin damage that some fish obtained due to bad weather conditions during the transport. The fish that were transported in June 2002 did not have a period of adaptation to the captivity and the fish were fed intensively immediately after transport, while in other cages feeding process was extensive in the beginning and the quantity of feed progressively increased.

Table 4. The values of fat, moisture, dry matter, protein and carbohydrate content in tuna muscles

Cage No.	Fat (%)	Dry matter (%)	Moisture (%)	Proteins (%)	Carbohydrates (%)
0*	0.90	19.64	80.36	13.77	0.31
1.	20.62	44.74	55.26	18.60	0.66
2.	42.50	60.05	39.95	16.00	0.37
3.	20.97	45.36	54.64	15.09	0.83
4.	20.57	50.30	49.70	20.58	0.57

*0 newly caught tuna prior feeding

DISCUSSION

In wild-caught tuna, stored fat was found to be less than 1% of the total body weight, compared to over 20% of the total body weight in aquacultured tuna. Continuous high-energy diet and lower activity may cause higher fat content in cultured fish (NAKAMURA *et al.*, 2007). The level of fat in the flesh partly depends upon the dietary fat levels (MOURENTE & TOCHER, 2009), the fish's capacity to digest proteins and feed conversion ratio (GRAHAM 1975). The composition of fats (except for cage 2; 42.50%) were lower, compared to previous studies in the bluefin tuna: 23.0% (NAKAMURA *et al.*, 2007), 27.5% (KAGAWA, 2001), and from 27.30% to 28.96% (MISLOV JELAVIC *et. al*., 2012). The highest fat content found in cage 2 (twice the value found in cage 1) could have different reasons. Firstly, the density of captive fish was lower (6,743 of individuals) compared to cage 1 (7,183 individuals), although fish were farmed for the same period of time (21 months). Also, fish from cage 2 had a lower initial biomass (on average 26.37 kg) compared to fish from cage 1 (on average 32.18 kg). Additionally, different hydrographic conditions (temperature and oxygen) might have attributed to such differences, since farming in cage 2 started a year later than in cage 1. According to GIMENEZ-CASALDUERO & SANCHEZ-JEREZ (2006) fat content is tightly related to the fish metabolism, therefore depends on the water temperature (higher in temperate water compared to tropical water), animal size (higher in large adults than in juveniles) and sexual maturity (higher before spawning than after spawning).

Interestingly, tuna kept in cage 1. that were farmed for two consecutive cycles (21 months) did not differ in fat, dry matter and moisture content compared to tuna farmed for five months. These results demonstrate that high fat content can be achieved already after five months of intensive feeding. The potential benefits of high fat diets such as rapid growth, may have to be balanced with potential deleterious effects such as reduced product quality and consumer acceptance (MOURENTE & TOCHER, 2009), although in tuna this is not the case. According to DOSDAT (2015) during the aquaculture process water is the vehicle for both feed and waste. Metabolic wastes and feed (uneaten and undigested feed, indigestible compound originating from food and excreta) result in water quality degradation, therefore water quality is an important variable to consider when planning feeding schemes in tuna aquaculture.

The observed moisture content in this study corresponds to the proximate composition of moisture in the ventral muscle of bluefin tuna (51.4%) according to the Standard Tables of Food Composition in Japan (KAGAWA, 2001). In Atlantic northern bluefin tuna, high body fat content and low water content usually indicates that the fish has stored enough energy in its muscle fat reserves for migrations (CLAY, 1988). Farmed fish showed higher fat and lower moisture content than wild specimens, due to a high dietary fat level in the feed and reduced activity (PERIAGO *et al.*, 2005). SIDWELL *et al.* (1974) found that bluefin tuna had fat content 3.9% and moisture content 70.4% due to their high protein content. For the tuna in this study the lowest fat percentage was 20.57% (Cage 4) while the highest moisture content was 55.26% (Cage 1) (Table 4.)

Higher content of proteins was also found in aquacultured tuna compared to wild-caught tuna, while there were no differences in protein content in tuna reared for one or two cycles. According to MOURENTE & TOCHER (2009), protein composition was observed to be less variable than fat composition, although the average composition of protein observed herein has been generally lower compared to other studies; 20.1% (KAGAWA, 2001), 21.09% (TOPIC POPOVIC *et al*., 2012) and 25.4% (BIMOL *et al*., 2010). Fish muscles that contain small amounts of protein tend to lose considerable water upon cooking, which negatively affects the texture of the meat (OKLAND *et al.,* 2005), making the protein content an important element in considering the quality and texture of the fish muscle (TOPIC POPOVIC *et al*., 2012). There are no differences in carbohydrates content between tuna reared for one and two cycles, as well as between farmed and NCTPF tuna. Carbohydrate originates from body glycogen which burns and regenerates is synthesized and degraded quickly, indicating that glycogen it is a less optimal parameter of muscle quality in farmed fish.

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Utjecaj hranidbe na sastav mišićnog tkiva plavoperajne tune (*Thunnus thynnus*) uzgajane u kavezima

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SAŽETAK

Kavezni uzgoj tune uhvaćene u divljini, tijekom razdoblja dužeg od jedne godine, sve dok tuna ne dobije znatno na težini, jedan je od najznačajnijih akvakulturnih aktivnost u Hrvatskoj. Cilj ovog rada je odrediti utjecaj intenziteta i duljine ishrane na biokemijski sastav bijelog mišićnog tkiva (ukupni sadržaj masti, vode, suhe tvari, ugljikohidrata i proteina) tek ulovljene tune (*Thunnus thynnus*) prije tovljenja, u odnosu na tunu uzgajanu u kavezima kružnog oblika između 2001. i 2004. u uvali Vela Grška, koja se nalazi na južnoj obali otoka Brača u hrvatskom dijelu Jadranskog mora (LAT 43°17'40,6984"N, LONG 016°28'58,4315"E (WGS84)). Tuna uzgajana u sva četiri kaveza hranjena je domaćom malom plavom ribom ili mješavinom haringe iz Sjevernog mora (*Clupea harengus*) i srdele (*Sardina pilchardus*), i to tijekom pet mjeseci (kavez 3), osam mjeseci (kavez 4) odnosno 21 mjesec (kavezi 1 i 2). Niski udjeli vode i visoki udjeli suhe tvari, uključujući masti, zabilježeni su u mišićnom tkivu uzgajane tune u odnosu na divlju tunu. U mišićnom tkivu kavezno uzgajane tune zabilježeno je 55.26% vode u kavezu 1, 39.95% u kavezu 2, 54.64% u kavezu 3 i 49.70% u kavezu 4, što su značajno niže vrijednosti od vrijednosti izmjerenih za divlju tunu (80.36%). Udio suhe tvari u mišićnom tkivu uzgajane tovljene tune značajno se razlikovao od udjela suhe tvari nađene u mišićnom tkivu divlje tune (19.64%), ali u mišićnom tkivu tuna uzgajanih u različitim kavezima (44.74% u kavezu 1, 60.05% u kavezu 2, 45.36% u kavezu 3 i 50.30% u kavezu 4).

Ukupne masti u mišićnom tkivu čine manje od 1% ukupne težine tijela divlje tune, dok su te vrijednosti u tovljenih tuna: 20.62% u kavezu 1, 42.50% u kavezu 2, 20.97% u kavezu 3 i 20.57% u kavezu 4. Ovi rezultati upućuju na to da se visok sadržaj masti može postići već nakon pet mjeseci intenzivnog tovljenja tune. Visoke vrijednosti udjela proteina nađene su u mišićnom tkivu uzgajanih tuna (18.60% u kavezu 1, 16.00% u kavezu 2, 15.09% u kavezu 3 i 20.58% u kavezu 4) u usporedbi s mišićnim tkivom divlje tune (13.77%).

Udio ugljikohidrata u mišićnom tkivu tuna nije se značajno razlikovao između tuna uzgajanih u različitim kavezima (0.83% u kavezu 1, 0.57% u kavezu 2.0 66% u kavezu 3 i 0.37 u kavezu 4), kao ni u usporedbi s mišićnim tkivom divljih tuna (0.31%). Kako ugljikohidrati potječu iz glikogena koji se brzo sintetizira i razgrađuje, sadržaj glikogena u mišićnom tkivu tune, manje je pogodan parametar za ocjenu kvalitete mišićnog tkiva uzgajane ribe.

Ključne riječi: plavoperajna tuna, sastav mišićnog tkiva, kavezni uzgoj, uvala Vela Grška