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SLAUGHTER AND MORPHOPHYSIOLOGICAL CHARACTERISTICS OF MALE STERLET (*Acipenser ruthenus* Linnaeus, 1758) OF DIFFERENT AGE, REARED IN A CAGE FARM

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Abstract

A comparative analysis of indicators related to the meat production of a male Sterlet at the age of six and seven summers raised on an industrial cage farm located in Southeastern Bulgaria was performed in the study. The slaughter yield and meat quantities, as well as indices relating to the exterior and interior of the fish, were calculated. Older fish have been found to be significantly heavier than younger ones, but age does not significantly affect the weight of individual body parts and exterior dimensions. It is a reliable source of variation only on the relative proportion of fillets without the abdomen in the cleaned carcass. The difference in favor of younger fish was 8.2% ($p \leq 0.05$). Fish of different ages do not differ significantly in the indexes related to exterior, interior and fatness. A significant difference in favor of younger fish ($p \leq 0.05$) was found only on the spleen-somatic index.

***Key words**: aquaculture, exterior indices, interior indices, meat production, sturgeon.*

INTRODUCTION

The condition of wild sturgeon populations is steadily deteriorating (Bronzi and Rosenthal, 2014). The development of sturgeon breeding is of particular importance for their conservation and restoration (Vasileva, 2015).
Bronzi et al. (2019) note that more and more production (caviar and meat) comes from Sturgeon aquaculture. In Bulgaria, Sturgeon breeding is developing well (Nikolova, 2019). The country ranks 8th in caviar production and 12th in Sturgeon biomass production (Bronzi et al., 2019).
A number of sturgeon species are cultivated in Bulgarian aquaculture (MAFF, 2019), and traditionally farmed Sterlet. Sterlet is the smallest representative of the Acipenseridae family. The life span is about 20 years, reaching a maximum length of 70-90 cm and a weight of 2-4 kg (Chebanov and Galich, 2013). Sterlet is successfully cultivated in different technologies, in different regions (Volkova, 2006; Rybnikár et al., 2011; Khudyi et al., 2014). Ak et al. (2019) identify the species as suitable for multicultural farming, and Skvortsova and Pavlova (2017) identify it as the most popular target for industrial fish farming.
At the same time, according to Saraiva (2020), knowledge of this species, both in the wild and in aquaculture, is not sufficient. The author notes the need for scientific research on this species in its cultivation on aquaculture farms. They affect the productivity of fish by the rearing technologies used (Prokeš et al., 2011; Akbulut et al., 2013), which is why it is important to conduct studies in specific conditions (Nikolova, 2013). In combination with genetic factors, environmental factors determine both body growth and body proportions in fish (Kirpichnikov, 1979; Kapusta et al., 2013).
In Bulgaria, Sterlet is reared in pure condition and used to produce hybrids. In Sturgeon farms with a full reproduction cycle, after the selection of producers to complete the reproductive herds, the remaining male individuals are used for meat. In this connection, the regularities of the development of the species and the meat-forming qualities, which are determined by them at different stages of life, are of interest. We have set ourselves the goal of conducting a slaughter and morphophysiological characteristic of male Sterlets at different ages, when reared in an industrial cage farm located in Southeastern Bulgaria.

MATERIALS AND METHODS

The study was carried out with male individuals of Sterlet (*Acipenser ruthenus* Linnaeus, 1758) from a net-cage farm located in a warm water reservoir. According to its type, the reservoir refers to large and deep reservoirs. Its area is 16.07 km^2, its volume is 532.9 x 106 m^3. The reservoir is located in South-Easthern Bulgaria, at 41º37 'N latitude and 25º20' E longitude. It falls into the South Rhodopian climatic region. The average altitude is about 280 m. Fish of different age groups were reared in separate net-cages. The cages were 8 × 8 m in size, the water depth being 6 m. Each cage had a double polyamide net. The average stocking density during the vegetation period was 4.28-5.20 kg/m³. Feeding was performed with a commercial granulated sturgeon feed (Table 1).

Table 1. Composition of commercial feed

Indices	Value	Indices	Value
Protein, %	46	Vitamin A, IU.kg^{-1}	10 000
Fat, %	15	Vitamin C, mg.kg^{-1}	520
Crude fibre, %	1.4	Vitamin E, mg.kg^{-1}	200
Ash, %	6.5	Vitamin D3, IU.kg^{-1}	2 303
Total P, %	1.03	Gross energy, MJ.kg^{-1}	21.0
Ca, %	1.4	Digestible energy, MJ.kg^{-1}	19.2
Na, %	0.3%		

Five individuals were randomly selected from each age group (six - (Ar_{5+}) and seven – summer - old (Ar_{6+}) at the end of the vegetation period (in November) for the morphophysiological analysis. Classical methods for exterior measurements and slaughter analysis of fish have been applied.
Total weight, kg - TW; Total length, cm - TL; Standard length, cm - SL; Fork length, cm - FL; Maximum body height, cm - BH; Maximum body width, cm - BT; Maximum body girth, cm - aO; Eviscerated weight (TW without intestines), kg - EW; Carcass weight (TW without intestines, whole head, fins and tail), kg - CW; Fins and tail, kg - FT; Head without gills, kg - Hw; Gills, kg - G; Bone plates, kg - Bp; Swim bladder, kg - Sb; Pyloric appendage, kg - Pa; Chord, kg - Ch; Fillet with skin, kg - FS; Fillet with skin without belly flap, kg - FSwB; Total viscera/insides/, kg - TV; Gonads, kg - GO; Heart, kg - Ht; Liver, g - LW; Spleen, kg - SW were measured for each fish.

The following indices were calculated: IHB - High-backed index - (SL/BH); IBB - Broad-backed index (BT/SL) * 100; IH - Hardness index - (aO/SL) * 100, %; CFF - Fulton's coefficient - (TW/SL^3) * 100, %; CFC - Clarc's coefficient (EW/SL^3) * 100, %; IC - Condition index - (TW/(SL * BH * aO)) * 100, %; ICR - Modified Fulton's coefficient by Jones et al. (1999) (according to Richter et al., 2000) - (TW/(SL^{2}BH)) * 100, %; VSI - Viscerosomatic index - (TV/TW) * 100, %; HSI - Hepatosomatic index - (LW/TW) * 100, %; GSI - Gonadosomatic index - (GO/TW) * 100, %; SSI - Spleensomatic index - (SW/TW) * 100, %; HtSI - Heartsomatic index - (Ht/TW) * 100, %; Sv1 - Slaughter value 1 (EW/TW) * 100, %; Sv2 - Slaughter value 2 (TW without intestines and gills/TW) * 100, %; Sv3 - Slaughter value 3 (CW/TW) * 100, %; Fy1 - Relative share of the fillet with skin from the live weight - (FS/TW)*100, %; Fy2 - Relative share of the fillet with skin from the carcass weight - (FS/CW)*100, %; My1 - Relative share of the fillet with skin without belly flap from the live weight - (FSwB/TW)*100, %; My2 - Relative share of the fillet with skin without belly flap from the carcass weight - (FSwB/CW)*100, %.
IBM SPSS Statistics 21 was used for statistical data processing.

RESULTS AND DISCUSSIONS

The exterior characteristics of the analyzed fish are presented in Table 2. Although the absolute values for these indicators are higher for fish of the older age group, age is not a reliable source of variation. A similar regularity was observed by Reshetnikov and Popova (2015), who, based on Coregonidae's own studies, found that plastic signs in fish are less closely related to age than to size and growth rate.

Table 2. Exterior characteristics of fish, cm

Indices	Ar_{5+}			Ar_{6+}		
	LS	±Se	SD	LS	±Se	SD
TL	68.72	0.836	1.672	73.26	1.223	2.446
FL	61.30	0.751	1.502	65.94	1.041	2.082
SL	57.70	0.826	1.652	60.54	2.087	4.174
BH	8.950	0.334	0.669	9.460	0.266	0.532
BT	8.580	0.566	1.132	11.68	0.985	1.969
aO	26.40	1.059	2.118	30.96	0.772	1.544

Prokeš et al. (2011) indicate that the most intense growth of Sterlet is at 1-2 years of age, and the adult period begins after 4-5 years of age. In the conditions of our studied by us, the Sterlet maintains good growth rates until later in life, with seven-summer-old fish 1.5 times ($p<0.01$) heavier than six-summer-olds (Table 3). Logically, in older fish, the absolute weights of individual body parts are higher. CW was heavier by 51.1%, whole fillet (FS) by 44%, cleaned fillet (FSwB) - 34.4%, all insides (TV) - 63.6%, fins and tail (FT) - 33.9% and head without gills (Hw) - 15.8%. Only six-summer-old fish, heavier by 2.9%, have bone shields (Bp), but the difference is not significant. Age is not a reliable source of variation in the weight characteristics of individual body parts as a whole.

Table 3. Weight characteristics, g

Indices	Ar_{5+}			Ar_{6+}		
	LS	±Se	SD	LS	±Se	SD
TW	1667.6**	136.3	267.8	2456.6**	192.8	337.9
CW	1055.2	82.75	165.5	1594.1	117.8	235.6
FS	927.6	90.52	181.0	1335.7	112.0	224.0
FSwB	825.2	83.81	167.6	1108.7	82.85	165.7
TV	291.0	60.83	121.7	476.0	54.84	109.7
GO	153.1	56.96	113.9	292.5	66.97	133.9
LW	55.71	5.454	10.91	74.84	2.066	4.132
SW	2.542	0.087	0.175	3.364	0.331	0.663
Ht	1.962	0.132	0.263	2.564	0.382	0.765
FT	65.75	1.558	3.116	88.01	5.862	11.72
Hw	222.7	8.491	16.98	257.9	18.37	36.74
G	29.70	1.654	3.308	40.57	5.846	11.69
Bp	62.57	5.442	10.88	60.76	8.299	16.60
Sb	2.410	0.275	0.549	6.400	1.151	2.302
Pa	0.858	0.212	0.425	2.354	0.392	0.784
Ch	20.35	3.246	6.493	26.43	6.396	12.79

**$P<0.01$

In terms of the weight of the individual internal organs, there are also differences in favor of older fish, respectively, in the liver - 34.3%; spleens - 32.3%; heart - 30.7%, but they are not significant. The biggest (91%) is the difference in the weight of the gonads in favor of older fish, which is also not significant. The development of gonads in fish can vary greatly within the same age and body weight. Thus, Skvorcova and Pavlova (2017), by comparing the morphological characteristics of Sterlet with relatively equal body weight, from different aquaculture farms, found more than 5 times the difference in the development of gonads. The authors point out that, as a whole, the weight of internal organs increases in parallel with the increase in the body weight of the fish.

The development of the fish can be determined by the dynamics of the relative proportions of the individual parts of the body (Table 4). In Sterlet, the head makes up for 12.62% (seven summers) to 15.35% (six summers) of body weight. Despite the fact that the head refers to conditionally consumable products, in sturgeon it has value because it makes a certain type of canned food (Lisovskaja et al., 2009). Sturgeon fish are also often prepared whole for the purpose, especially for smaller species. In all cases, when using the head, the gills are removed, which in our case reduces its weight by 11.8-13.6%.

Table 4. Relative proportions of the individual parts of the body, % of the body weight

Indices	Ar_{5+}			Ar_{6+}		
	LS	±Se	SD	LS	±Se	SD
Hw	13.55	0.882	1.764	10.51	0.371	0.743
G	1.798	0.094	0.187	1.650	0.199	0.399
FT	4.007	0.259	0.518	3.584	0.033	0.067
Sb	0.145	0.015	0.029	0.260	0.037	0.074
Pa	0.052	0.014	0.029	0.096	0.016	0.032
Ch	1.236	0.190	0.379	1.102	0.266	0.533
Bp	3.873	0.555	1.110	2.488	0.318	0.636

When Sterlet is prepared as a whole dish, chords are removed in addition to the gills (Ratushniy and Aminov, 2017). Chord in sturgeon species can be referred to consumable products, and in Russia it is known as 'vyaziga' (Vlasova and Frensis, 2007). The relative proportion of chord in our study ranged from 1.1 to 1.2 and decreased with age.

Fish is a unique product that is subject to a full processing. Waste from fish processing, except for the production of fishmeal, can be used in various fields of production. Swimming bladders from Sturgeon fish are used to clarify beverages and for the production of fish glue, the latter being 15-20% by weight of feedstock (Koochekian et al., 2006).

The use of non-traditional raw materials is expanding in various industries. Thus, there is a growing interest in medicine for fish swimming bladders. Ivanova and Petrova (2015) noted that, in medicine, fish collagen and its hydrolysis products are widely used for the treatment of wounds, skin burns, ulcers, pulps, osteoarthritis and hypertension. The authors obtained positive results from a study of the possibility of using the Siberian sturgeon swimming bladder as a source of collagen for the production of medical supplies (adhesive and film for superficial wounds).

In our study, at six- and seven-summer-olds, the swimming bladder accounts for 0.145 and 0.260%, respectively, of the body weight, with its relative proportion increasing almost twice with age. In older fish, the relative share of the pyloric appendage is also higher, with a difference of 1.8 times.

In general, it can be summarized that the proportion of head without gills and gills decreases with age. The same applies to other parts of the body, except the pyloric appendage and the swimming bladder, where the difference is in favor of older fish.

Slaughter indices are decisive in the evaluation of animals grown for meat. They depend on both genetic and paratype factors. Thus, Souza et al. (2015), when studying the effect of rainbow trout body weight on processing yield and chemical composition, found that fish with a lower body weight had higher yield for the whole eviscerated fish and head, but a lower yield for the viscera.

We have calculated three of the main ones recommended by Todorov and Ivancheva (1992) in fish farming, yields - slaughter (Sv1), consumable (Sv2) and for the canning industry (Sv3) (Table 5). Sv1 and Sv2 were higher in the Sterlet at an earlier age by 2.9% and 2.7%, respectively, and Sv3 were higher than those at an older age (2.4%), but the differences were not significant.

Table 5. Slaughter indicators, %

Indices	Ar_{5+}			Ar_{6+}		
	LS	±Se	SD	LS	±Se	SD
Sv1	82.9	2.29	4.58	80.6	1.83	3.65
Sv2	81.1	2.28	4.55	78.9	1.84	3.68
Sv3	63.4	1.71	3.41	64.9	1.64	3.28
Fy1	55.4	1.30	2.60	54.3	2.32	4.63
Fy2	49.2	1.34	2.68	45.2	2.16	4.36
My1	87.5	2.15	4.30	83.6	1.75	3.49
My2	77.8*	2.13	4.26	69.6*	1.86	3.73

*P<0.05

Whole Sterlet fillet, at the studied age, constitutes 54.3-55.4% of the body weight, with the difference in Fy1 favoring younger fish being 1.1%. The difference in Fy2 is greater - 4%. This shows that the proportion of valuable muscles decreases with age, but the differences found are not significant. Higher, but again not significant, in six-summer-old fish, the relative share of whole (My1) and of the filet in the cleaned carcass (My2) is also high. Age is a significant source of variation only on My2. The difference in favor of younger fish is 8.2% ($p \leq 0.05$).

The morphophysiological method for assessing regularity of growth and development is often applied to both fish and warm-blooded animals, although the principles of manifestation of morphophysiological regularity are different (Bolshakov, 2019). In fish studies, indices related to constitution, exterior, fatness, and development of internal organs are sources of information about the condition of individuals and their well-being (Smirnov et al., 1972; Dzyubuk and Klyukina, 2014 etc.).

Dekic et al. (2016) point out condition factor and organosomatic indices of fish as tools for assessing the impact of environmental factors on fish. In fish farmed on aquaculture farms, morphophysiological indicators are examined using different technologies. Thus, Molchanova and Khrustalyov (2017) found in rainbow trout reared in RAS changes on a number of plastic features. Kuritsyn et al. (2017) have applied the morphophysiological method for analyzing the physiological status, health status and general well-being of rainbow trout and muksun when grown in cages. The authors state that the absolute and relative dimensions of the internal organs of different fish species differ and depend on the conditions under which the fish are farmed. For example, the weight of the heart is related to the activity and energy balance in body; liver weight - with metabolic processes; the spleen is an important hematopoietic organ, also associated with fish metabolism; the relative share of all the viscera can be used as a biotest for physiological features related to nutrition, etc.

Lenhardt et al. (2012), when comparing the morphological characteristics of wild and cultivated aquaculture Sterlet, found significant differences on 11 traits. Farm-raised fish had a shorter pectoral fins and stockier body. Jankowska et al. (2007) also found differences in slaughter yield, proximate composition and flesh color of cultivated and wild perch.

Table 6 shows the morphometric and morphophysiological indices of six- and seven-summer-old Sterlets. The high backed index (IHB) is practically the same for fish of both age groups. For the bold backed index (IBB), the difference (4.4%) is in favor of older individuals. Fish of this age are also more compact (with a higher hardness index - IH), with a difference of six summers at 5.5%. Seven-summer-old fish are also higher in all condition-related indices (CFF; CFC; IC; ICR).
The Fulton coefficient (CFF) for the two age categories ranges from 0.865 to 1.115, and in principle it can vary considerably. In accessible literature, much of the CFF information is about early age Sterlet.

Table 6. Morphometric and morphophysiological indices

Indices	Ar_{5+}			Ar_{6+}		
	LS	±Se	SD	LS	±Se	SD
IHB	6.472	0.230	0.459	6.403	0.183	0.367
IBB	14.87	0.934	1.868	19.30	1.509	3.018
IH	45.75	1.656	3.313	51.22	1.004	2.007
CFF	0.865	0.051	0.103	1.115	0.082	0.165
CFC	0.714	0.024	0.048	0.901	0.078	0.155
IC	12.19	0.323	0.646	13.83	0.440	0.880
ICR	5.565	0.170	0.341	7.099	0.370	0.741
VSI	17.06	2.288	4.576	19.37	1.825	3.650
HSI	3.350	0.268	0.536	3.092	0.230	0.459
GSI	8.746	2.592	5.184	11.75	2.520	5.041
SSI	0.156*	0.016	0.032	0.138*	0.016	0.032
HtSI	0.119	0.009	0.018	0.106	0.019	0.038

*P<0.05

Lenhardt et al. (2012) indicate average values of about 0.42 in a growing up Sterlet from natural populations, and for aquaculture farm Sterlets - 0.30. In a study by Skvorcova and Pavlova (2017) of a Sterlet with an average age of 2.5 years reared on different aquaculture farms, CFF was similar, with a high degree of variation of the indicator, ranging from 0.33 to 1.18 on one of the farms and from 0.57 to 0.65 on another. CFF remains an important index in fish research, despite its shortcomings. Kolisnyk et al. (2014) indicate that CFF shows not only the level of nutrition and quality of the natural food base, but also the ability of fish to absorb available food. CFF correlates with body composition, showing that slender fish contained less fat (Rønsholdt, 1995). CFF depends on fish age, gender, fullness of gut, amount of fat reserve and degree of muscular development etc. (Barnham and Baxter, 1998). The authors, pointing out the stage of maturation impact on CFF, indicate that gonads can take up to 15% of fish body weight. In our study, the gonadosomatic index (GSI) was 8.75-11.75%.
Regardless of the found age differences, between the six- and seven-summer-old Sterlets the differences in indexes related to the exterior and fatness are not significant. A significant difference in favor of fish at an earlier age (p <0.05) was found only on the spleensomatic index (SSI). With age, the index decreases from 0.156 to 0.138. Kuritsyn et al. (2017) indicate that SSI of rainbow trout is highly labile. The authors found that with age, the heartsomatic index (HtSI) decreased and the viscerosomatic index (VSI), hepatosomatic index (HSI) and CFF increased. A number of studies show that the growth and development of fish is not directly dependent on its age. Thus, in a study of the rainbow trout, Reinitz (1983) found that age cannot be determined as a major determinant of body composition. The content of the individual components (protein, fat etc.) is determined not by the age of the fish, but by its body weight. Shearer (1994) also notes the importance of fish body weight as a factor in forming body composition.

CONCLUSIONS

Seven-summer-old fish are significantly heavier than six-summer-old fish, but age does not significantly affect the weight of individual body parts and exterior indicators.
The slaughter yield Sv1 (eviscerated weight to total weight) and consumable slaughter value (Sv2 - total weight without intestines and gills to total weight) are higher in fish at an earlier age, 82.9% vs. 80.6% and 81.1% vs. 78.9%, respectively. The slaughter value for the canning industry (Sv3 - carcass weight to total weight) at six and seven summers of age is 63.4 and 64.9%, respectively. However the differences between these indicators are not significant.
It is a significant source of variation only on the relative proportion of fillets without the abdomen in the cleaned carcass. The difference in favor of fish at an earlier age was 8.2% (p≤0.05). Fish of different ages do not differ significantly in the indexes related to exterior, interior and fatness. A significant difference

(p≤0.05) in favor of younger fish was found only on the spleensomatic index.

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