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SLAUGHTER YIELD AND MORPHO-PHYSIOLOGICAL CHARACTERISTICS OF SIBERIAN STURGEON (*ACIPENSER BAERII*) REARED IN NET CAGES

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Abstract

The study was carried out with a four-summer-old male Siberian sturgeon, reared in net cages, installed in a large warm reservoir in Bulgaria. Two groups of fish were formed for the purpose of the analysis made at the end of the vegetation period – with lower (2823.0 ± 126.04 g) and higher (4273.2 ± 110.29 g) live weight. Fish of the first group had significantly lower weight of the carcass, fillet, total insides, gonads, liver, fins and tail, head without gills, gills, swim bladder and chord, compared to fish with higher live weight. The two groups did not differ significantly in the weight of heart, spleen and bone plates. In the frames of the experiment, the eviscerated weight and the relative share of carcass in the total body weight was 86.40-86.86% and 57.07-61.52%, respectively. The relative share of the whole fillet with skin in the body and in the carcass was 45.61-50.75% and 78.37-82.54%, respectively. All the parameters characterizing the slaughter value showed better results in fish with higher live weight, but the difference between the groups was significant only in the relative share of the fillet in the carcass (4.16%, $p<0.001$). All the indices of fish condition were higher in the group with higher live weight, the difference being significant in the condition index IC ($p<0.01$) and in the modified Fulton's coefficient ICR ($p<0.05$). Referring to the interior indices, no clear dependencies were established related to fish live weight. The viscerosomatic and cardiosomatic indices were higher in the smaller fishes, and the hepatosomatic, spleen-somatic and gonadosomatic indices – in the heavier representatives, the difference being significant only in the latter index ($p<0.05$).

Keywords: sturgeon; aquaculture; condition index; slaughter yield; fillet yield

INTRODUCTION

The development of sturgeon aquaculture is important for the supply of the market with delicacies – caviar and meat. Today, sturgeon farming is becoming a major tool for the conservation of naturally endangered populations (Kuderski, 2015; Vasileva, 2015).

Sturgeon rearing in aquaculture farms is practiced in a number of countries. Bulgaria ranks eighth in the world in caviar production and twelfth in sturgeon biomass production (Bronzi et al., 2019). The production parameters of fish largely depend on the breeding technologies (Prokeš et al., 2011; Akbulut et al., 2013; Nikolova, 2013; Barulin, 2015). Most sturgeon species are reared in super-intensive farms, 21% of them being recirculation aquaculture systems (RAS) and 18% – cages (Bronzi et al., 2019). When reared in commercial fish farms, fish is placed under unusual conditions. In this regard, the regularities in the development of different sturgeon species and their meat-production capacity in the conditions of specific industrial technologies are of interest to the researchers (Nikolova et al., 2018).

Siberian sturgeon is a world leader in sturgeon meat production. The species also occupies an increasing share in Bulgarian sturgeon farming (Nikolova, 2019). Siberian sturgeon has a good adaptability to industrial conditions. The species is tolerant to high stocking density (Hasanalipour et al., 2013). At the same time, when reared in commercial farms, abnormalities in fish development can be observed, such as scoliosis, which hampers normal nutrition (Duman, 2019).

Siberian sturgeon has been largely studied as an object of rearing, with an attention being paid mainly to the initial stages of life. Different approaches to breeding and feeding have been studied in young individuals (Koksal et al., 2000; Geraylou et al., 2013; Morshedi et al., 2017; Jafari et al., 2018; Józefiak et al., 2019, etc.) . The productive characteristics and meat quality of the growing Siberian sturgeon and its hybrids were investigated (Kolman et al., 2002, 2003; Jankowska et al., 2005).

In farms with a full cycle of reproduction, after choosing the producers to replenish the reproductive schools, the remaining males are sold for meat. When rearing Siberian sturgeon in cages in Bulgaria, the sex can be determined at the age of three (Bonev, 2018) and the selection of fish for the reproduction can be started earlier.

The aim of this study was to investigate a slaughter and morpho-physiological characteristics of male Siberian sturgeon (*Acipenser baerii*, Brandt, 1869), when reared in a commercial cage farm located in South-Eastern Bulgaria.

MATERIALS AND METHODS

The study was carried out with a four-summer-old male Siberian sturgeon (*Acipenser baerii* Brandt, 1869). Fish was reared in net cages, the farm being located in Kardzhali Reservoir. The water body refers to the large, deep reservoirs – its area is 16.07 km^2 and the volume 532.9×10^6 m^3. Kardzhali Reservoir is located in South-Eastern Bulgaria at 41°37' N latitude and 25°20' E longitude. It falls in the Southern Bulgaria climatic zone, Eastern Rhodope climatic region. The average altitude is about 280 m AMSL.

Fish of different species and categories was reared in separate cages on the farm. Fish sex was determined using ultrasound diagnostic methods, after which the males and the females were reared separately. The cages were 8×8 m in size with a depth of 6 m below the water surface. Each cage was equipped with double polyamide nets. The average stocking density during the growing season was 20 $kg.m^{-2}$. During the vegetation period, fish growth was monitored by dividing them according to their live weight. Feeding was performed with commercial specialized sturgeon granular extruded mixtures (Table 1).

Table 1. Composition of the 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%		

For the morphophysiological analysis made at the end of the vegetation period (November), two groups of five fish with lower (BW1) and higher (BW2) live weight were randomly formed. Tables 2 and 3 present the studied indicators and the codes with which they were labelled.

Table 2. Investigated characteristics

Parameters	Sign
Total weight, g	TW
Total length, cm	TL
Standard length, cm	SL
Maximum body height, cm	BH
Maximum body width, cm	BT
Maximum body girth, cm	aO
Eviscerated weight, kg	EW
Total intestines, g	It
Gonads, g	GO
Liver, g	LW
Spleen, g	SW
Heart, g	Ht
Swim bladder, g	Sb
Pyloric appendage, g	Pa
Fins and tail, g	FT
Head without gills, g	Hw
Gills, g	G
Bone plates, g	Bp
Fillet with skin, g	FS
Fillet with skin without belly flap, g	FSwB
Carcass weight (Total weight without intestines and whole head), g	CW
Slaughter value 1 (Eviscerated weight/Total weight)*100, %	Sv1
Slaughter value 2 (Total weight without intestines and gills/ Total weight)*100, %	Sv2
Slaughter value 3 (Carcass weight/Total weight)*100, %	Sv3

Each fish was a 2Asubject to exterior measurements (Pravdin, 1966). Classical methods for slaughter analysis of fish were applied (according to Todorov and Ivancheva, 1992; Pokorni, 1988; Prikryl and Janecek, 1991). The morpho-physiological and morphometric indices were calculated.

IBM SPSS Statistics 21 was used for statistical processing.

Table 3. Investigated morphometric and morpho-physiological indices

Indices	Sign
Fulton's coefficient $(TW/SL^3)*100$), %	CFF
Clarc's coefficient $(EW/ SL^3)*100$), %	CFC
Condition index (TW/(SL*BH*aO)*100), %	IC
Modified Fulton's coefficient [a], $(TW/(SL^2BH))*100$)	ICR
High-backed index (SL/BH)	IHB
Broad-backed index (BT/SL)*100, %	IBB
Hardness index (aO/SL)*100), %	IH
Viscerosomatic index (EW/TW)*100,%	VSI
Hepatosomatic index (LW/TW)*100, %	HSI
Gonadosomatic index (GO/TW)*100,%	GSI
Spleensomatic index (SW/TW)*100, %	SSI
Heartsomatic index (Ht/TW)*100, %	HtS

[a] by Jones et al., 1999 (according Richter et al., 2000)

RESULTS AND DISCUSSION

Table 4 presents the characteristics of the studied fish from the different groups of body weight.

Under the conditions of the studied technology, Siberian sturgeon gained in weight well. At the age of four summers, the average live weight in the group of smaller fish was

2823.0, and in the group of larger ones – 4273.2 g, the difference between the groups being 1.5 times (*p <0.001*). The difference in total length was 11.7% in favour of the heavier fish, in fork length and in standard length – 11.5 and 10.5%, respectively. Body height, body width and body girth were also larger in fish with higher live weight – 7.3, 10.8 and 10.3%, respectively. Despite the higher values for all the exterior indices in fish of the second group, the differences between the groups were insignificant.

Table 4. Characteristics of fishes at different groups

Indices	BW 1			BW 2		
	ΔX	±SE	SD	ΔX	±SE	SD
Total weight, g	2823.00a	126.044	281.844	4273.2a	110.288	246.611
Total length, cm	88.14	2.178	4.870	99.82	0.723	1.617
Fork length, cm	76.12	1.947	4.353	85.98	0.881	1.969
Standard length, cm	71.98	1.761	3.939	80.46	0.331	0.740
Max. body height, cm	9.90	0.100	0.224	10.68	0.208	0.466
Max. body width, cm	10.78	0.196	0.438	12.08	0.213	0.476
Max. body girth, cm	31.40	0.579	1.294	35.00	0.389	0.869

Values with the same letters in the rows are significantly different: a - p<0.001

In smaller fish, significantly lower values were established for the carcass weight (37.5%, *p <0.001*), fillet (40.5%, *p <0.001*), fillet without belly flap (57.5%, *p <0.001*), total insides (42.4%, *p <0.05*), gonads (65.6%, *p <0.05*), liver (39.7%, *p <0.05*), fins and tail (28.6%, *p <0.001*), head without gills (25.1%, *p <0.01*), gills 28.8%, *p <0.01*), swim bladder (38.8%, *p <0.001*) and chord (21.7%, *p <0.05*). Fish from the two weight groups did not differ significantly in heart, spleen and bone plate weights (Table 5). The relative shares of the separate organs and body parts in fish characterize their development. Mousavi-Sabet et al. (2019) emphasized that data on the biometric characteristics of sturgeon reared in aquaculture, can be useful as key values in the studies of introduced species of that family, inhabiting natural ecosystems.

Keszka et al. (2009), underlying the importance of studies of the morphological characteristics of fish reared in aquaculture, indicated that in the first two summers of life of cultured Siberian sturgeon, most of the metric characters have allometric growth, which is influenced by the specific conditions of the rearing technology.

There was no significant difference in the relative share of the different body parts between the studied groups (Table 6). There was practically no difference in the slaughter characteristics as well.

The biggest difference was established in the relative share of carcass in the total body (Sv3). It was 58.07% for the fish from the first group and for those from the second – 61.52%, but the difference of 3.5% between the groups was insignificant.

Kolman et al. (2002) established higher values of the relative share of the carcass (69.68%) in Siberian sturgeon with a body weight of 1 415 g, compared to those in the present study.

In a morphological analysis of three-summer-old Siberian sturgeon with an average live weight of over 2000 g, reared in a warm-water net cage farm, Nikiforov (2009) found 82% eviscerated weight. In the present study, the values of that indicator (SV1) were higher (86.40-86.86%), the maximum values being reported for the fish from group BW1.

In a study of several sturgeon species, including Siberian sturgeon, Badiani et al. (1999) established a significant effect of the species on the eviscerated yield, white flesh yield, viscera and gonado-somatic indices and no effect on the dressed yield. Regarding the effect of fish live weight on slaughter characteristics and meat quality, there are quite controversial data. A number of studies show that the whole fish weight exerts an effect on the processing yields. Thus, in a study of Gulf sturgeon, Oliveira et al. (2008) found that the relative share of fillet yields increased with the increase of the body weight.

Table 5. Absolute values of the slaughter analysis of fishes, g

Indices	BW 1			BW 2		
	ΔX	±SE	SD	ΔX	±SE	SD
Carcass weight	1646.12a	126.118	282.009	2633.83a	127.325	284.708
Fillet with skin	1293.20a	11.473	247.025	2173.60a	110.626	247.368
Fillet with skin without belly flap	1084.40a	121.167	270.937	1884.00	74.576a	166.757
Total insides	381.40c	21.826	48.804	560.80c	58.157	130.043
Gonads	65.12c	26.969	60.304	189.31c	33.979	75.979
Liver	58.84c	11.812	26.413	97.55c	10.039	22.448
Spleen	4.11	0.695	1.554	6.53	1.288	2.881
Heart	3.26	0.485	1.085	3.67	0.115	0.258
Fins and tail	163.07a	7.885	17.631	228.41a	5.681	12.704
Head without gills	551.87b	30.655	68.546	736.98b	20.290	45.370
Gills	80.54b	6.224	13.917	113.18b	20.290	45.370
Bone plates	79.80	23.892	53.424	87.48	11.605	25.951
Swim bladder	24.00a	2.025	4.528	39.20a	1.158	2.588
Chord	56.10c	4.197	9.385	71.65c	2.371	5.303

Values with the same letters in the rows are significantly different: a- p<0.001; b- p<0.01; c -p<0.05

Table 6. Slaughter characteristics of fishes, %

Indices	BW 1			BW 2		
	ΔX	±SE	SD	ΔX	±SE	SD
Slaughter value 1	86.40	0.904	2.021	86.86	1.384	3.095
Slaughter value 2	83.51	1.117	2.498	84.19	1.417	3.168
Slaughter value 3	58.07	2.463	5.507	61.52	1.836	4.105
Relative share of the live weight						
Head without gills	19.64	1.156	2.584	17.30	0.717	1.603
Gills	2.89	0.283	0.632	2.67	0.213	0.475
Fins and tail	5.81	0.312	0.698	5.37	0.225	0.502
Swim bladder	0.86	0.075	1.666	0.92	0.029	0.064
Chord	2.00	0.170	0.379	1.68	0.064	0.142

Bone plates	2.82	0.853	1.907	2.06	0.285	0.637
Fillet with skin	45.61	2.541	5.682	50.75	1.466	3.278
Fillet with skin without belly flap	38.06	3.161	7.068	44.04	0.897	2.007
Relative share of the carcass weight						
Fillet with skin	78.38a	1.640	3.667	82.54a	1.164	2.603
Fillet with skin without belly flap	65.19	3.391	7.583	71.73	1.595	3.567

Values with the same letters in the rows are significantly different a- p<0.05

The authors announced that fish must be at least 2.5 kg in weight in order to provide 60% headed and gutted yields. Ghomi et al. (2013) established the effect of live weight on meat quality of beluga. In studies carried out by Intarak et al. (2015), body weight did not have a significant effect on carcass quality (dressing and fillet percentage) in punga fish, while Souza et al. (2015) reported that body weight had an effect on the yield and the relative share of the head in rainbow trout, but did not affect the relative share of the fillet.

The amount of muscle in the carcass is one of the major indicators characterizing fish quality. The indicator may depend on a number of technological factors and it varies considerably in different species. In studies of Gulf sturgeon, the dressed fillet yields were within 19-23% of the total body weight (Oliveira et al., 2008).

Chapman et al. (2005) in a study of meat yields in Russian and Siberian sturgeon with a live weight of 2.3-2.6 kg, found that dressed fillet yields depended on fish species. The skinless fillet yield in Siberian sturgeon was 32%.

Kolman et al. (2002) established 76.98% fillet with skin in the cleaned carcass of Siberian sturgeon. Those results are close to the results obtained in the present study for fish of BW1 group (78.37%). In fish with higher live weight (group BW2), the relative share of the fillet in the cleaned carcass was 82.54%. The relative share of the whole fillet in the four-summer-old Siberian sturgeon was 45.61% in BW1 and 50.75% in BW2, and, the cleaned fillet without belly flap – 38.06% and 44.04%, respectively. The amount of fillet was higher in fish with higher live weight, but the difference was significant only in the relative share of fillet in the carcass (4.16%, $p < 0.001$).

The calculated indices of Siberian sturgeon from the two weight groups are presented in Table 7.

Table 7. Morphometric and morpho-physiological indices of fish at different groups

Indices	BW 1			BW 2		
	ΔX	±SE	SD	ΔX	±SE	SD
IHB	7.28	0.225	0.502	7.55	0.170	0.380
IBB	15.02	0.540	1.208	15.01	0.261	0.584
IH	43.71	1.172	2.620	43.50	0.451	1.008
CFF	0.76	0.042	0.094	0.82	0.024	0.054
CFC	0.66	0.036	0.081	0.71	0.026	0.057
IC	12.60b	0.275	0.615	14.21b	0.121	0.271
ICR	5.51a	0.197	0.440	6.18a	0.109	0.243

VSI	13.60	0.904	2.021	13.14	1.384	3.095
HSI	2.06	0.351	0.784	2.27	0.185	0.415
GSI	2.18a	0.827	1.849	4.37a	0.697	1.557
SSI	0.14	0.019	0.043	0.15	0.031	0.069
HtSI	0.12	0.018	0.041	0.09	0.003	0.006

Values with the same letters in the rows are significantly different: b- $p<0.01$; a -$p<0.05$

Exterior and interior indices are widely used in fish studies (Hansson et al., 2017). Morphometric indices, including Fulton's coefficient, characterize the body condition and make it possible to estimate indirectly the fat content of fish (Hards et al., 2019). Fulton's coefficient in sturgeon species from natural populations can vary greatly, i.e. from 0.35 (*A. stellatus*) to 0.78 (*H. huso*), (Mousavi and Ghafor, 2014).

In the present study, we calculated several indices related to fish condition (Table 3). Fish with higher live weight had a higher index of fattening IC and ICR, the difference being 1.61% ($p <0.01$) and 0.67% ($p <0.05$), respectively. No significant difference was found in the other fattening indices – CFF and CFC, but in the fish from BW2 group the values were higher again.

In a study of two-summer-old Siberian sturgeon reared in tanks, Yazdani Sadati (2006) reported a decrease in the relative weight of heart (from 0.25 to 0.16-0.17%), digestive tract (2.6 to 1.9%) and spleen (0.6 to 0.3%) with the increase of fish live weight. In the present study, a clear tendency related to the interior indices and fish live weight was not established. VSI and HtSI were higher in smaller fish and HIS, GSI, SSI in heavier representatives. Only the difference in GSI between the groups was significant (2.19%, $p <0.05$). In a study of Siberian sturgeon reared in a cage farm, Nikiforov (2009) found a liver index of 2.86% and a spleen index of 0.27%. In the present study, the values of HSI and SSI were lower, 2.06-2.27% and 0.14-0.15%, respectively.

CONCLUSIONS

Siberian sturgeon, when reared in net cages installed in a large warm-water reservoir, is well-developed and has good slaughter characteristics at the age of four summers. Fish with smaller live weight had significantly lower weight of the carcass, fillet, total insides, gonads, liver, fins and tail, head without gills, gills, swim bladder and chord, compared to fish with higher live weight. The two groups did not differ significantly in the weight of heart, spleen and bone plates. In the frames of the experiment, the eviscerated weight and the relative share of carcass in the total body weight was 86.40-86.86% and 57.07-61.52%, respectively. The relative share of the whole fillet with skin in the body and in the carcass was 45.61-50.75% and 78.37-82.54%, respectively. All the parameters characterizing the slaughter value showed better results in fish with higher live weight, but the difference between the groups was significant only in the relative share of the fillet in the carcass (4.16%, $p<0.001$). All the indices of fish condition were higher in the group with higher live weight, the difference being significant in the condition index IC ($p<0.01$) and in the modified Fulton's coefficient ICR ($p<0.05$). Referring to the interior indices, no clear dependencies were established related to fish live weight. The viscerosomatic and cardiosomatic indices were higher in the smaller fish, and the hepatosomatic, spleen-somatic and gonadosomatic indices – in the heavier representatives, the difference being significant only in the latter index ($p<0.05$)

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