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INFLUENCE OF FARMING TECHNOLOGY ON DRY MATTER CONTENT IN RAINBOW TROUT (*ONCORHYNCHUS MYKISS* WALBAUM) MUSCLE TISSUE

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Abstract

Environmental and economic factors related to water exploitation have resulted in the development of recirculation techniques by trout fish farms. This study assesses the influence of farming technology on the content of dry matter in rainbow trout (*Oncorhynchus mykiss* Walbaum) muscles. Farming technology did not influence the dry matter content: mean content amounted to 25.7% in muscle tissue of trout caught in farms producing fish in recirculated water and 25.9% for fish from farms using flow-through water. Irrespective of the farming system, the catching season significantly influenced the dry matter content; in spring, dry content of muscle tissue of trout amounted to 25.3% and in autumn it was 26.3%. The place of catching (farm) influenced the dry matter content stronger in autumn than in spring. The kind of feed also influenced the dry matter content in rainbow trout muscle tissue depending on the season of catching.

WPŁYW TECHNOLOGII CHOWU NA ZAWARTOŚĆ SUCHEJ MASY W TKANCE MIĘŚNIOWEJ PSTRĄGA TĘCZOWEGO (*ONCORHYNCHUS MYKISS* WALBAUM)

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Słowa kluczowe: system recyrkulacji akwakultury, układ przepływowy, zawartość suchej masy, tkanki mięśniowej.

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A b s t r a k t

Środowiskowe i ekonomiczne uwarunkowania wykorzystywania wody spowodowały rozwój technik recyrkulacyjnych na farmach pstrągowych. Oceniono wpływ technologii chowu na zawartość suchej masy w mięśniach pstrąga tęczowego (*Oncorhynchus mykiss* Walbaum). Technologia chowu nie miała wpływu na zawartość suchej masy: średnia zawartość suchej masy w mięśniach pstrągów odłowionych w gospodarstwach produkujących na wodzie recyrkulowanej wynosiła 25.7%, zaś 25.9% – w mięśniach ryb z farm stosujących jednokrotny przepływ wody. Niezależnie od systemu chowu, sezon odłowu znacząco wpływał na zawartość suchej masy; wiosną tkanka mięśniowa pstrąga zawierała 25.3% a jesienią – 26.3% suchej masy. Miejsce odłowu (farma) silniej wpływało na zawartość suchej masy jesienią, niż wiosną. Również rodzaj paszy miał wpływ na zawartość suchej masy w mięśniach pstrąga tęczowego w zależności od sezonu odłowu.

Introduction

Diminishing marine resources have resulted in an appreciable increase in fresh water organisms and aquaculture is nowadays becoming the most rapidly developing sector of the agriculture and food industry. In 2011, 64 million tons of fish were produced by aquaculture world-wide and this was 244% of the world;s production of beef meat, 141% of pork meat and 171% of poultry meat (FAO 2012, FAOSTAT). In Poland, in 2010, the production of fresh water fish amounted to 30,757 tons, together with 12,940 tons of trout (FAO 2010).

Rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792) was introduced to Poland from Canada at the end of the 19th century. Trout-breeding has been a subject of interest to fish-farmers and this is why trout, together with carp, became the most common fish in Polish aquaculture (TEODOROWICZ 2013, TKACZEWSKA and MIGDAŁ 2012). Trout is a cold water fish, living in a river environment. Clear and well oxidized water is a condition necessary for trout breeding. Rainbow trout production technology is based on breeding under near-natural conditions, using flow-through water technology (TURCHINI et al. 2004). Opened breeding facilities (FTS), based on single-flow-through water, consume on average 200–400 l of water per second for a production of 40 do 200 tons of trout per year (TURCHINI et al. 2004, LEVER et al. 2004, SINDILARIU et al. 2009). The kind of farming technology and environmental conditions are among the most important parameters determining the quality and nutritional properties of trout (ROQUE D'ORBCASTEL et al. 2008, SZCZEPANIK et al. 2011, TKACZEWSKA and MIGDAŁ 2012).

In countries with limited water resources, conserving water is necessary. In Poland, the EPRA project (Environmental Protection in Rural Areas) aims to reduce the nitrogen contribution to surface and ground waters from agricultural sources (MANTEUFFEL SZOEGE and SOBOLEWSKA 2004). Although minimizing of environmental contamination due to fish production is also desirable (ROQUE D'ORBCASTEL et al. 2008), a balance needs to be struck between protecting the environment and employing profitable production technology. Increasing production yields is not possible when applying traditional methods of fish farming and meeting the strict demands of environmental protection. To lower production costs, producers are increasingly introducing water recirculation systems (RAS – Recirculation Aquaculture Systems) to re-use the water several times using filtration or chemical purification (DALSGAARD et al. 2013). However, Commission Regulation (WE) Nr 710/2009 (2009) lays down detailed rules on organic aquaculture production and does not allow the use of water recirculation in organic production until further studies are completed.

The aim of this study was to assess the effect of farming technology on dry matter content in rainbow trout muscle tissue.

Material and Methods

Material

Rainbow trout (*Oncorhynchus mykiss* Walbaum) was collected from six Polish farms: three of them produce fish by applying a flow-through water system and the other three farms use water recirculation (Fig. 1). Fish were fed

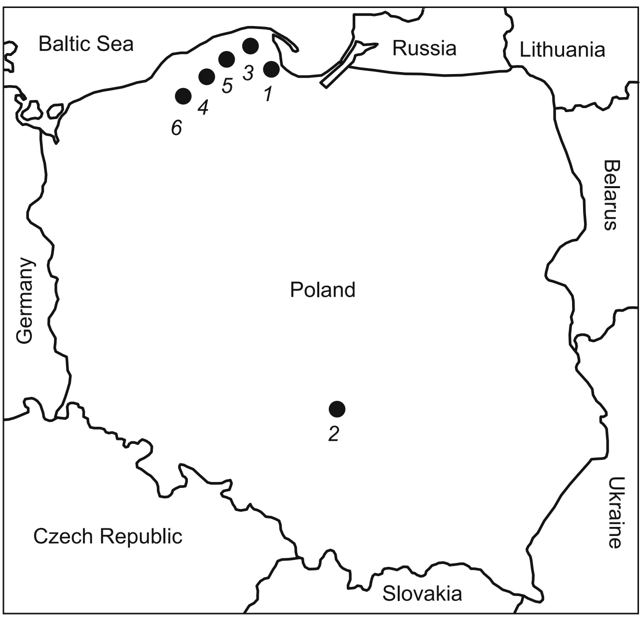

Fig. 1. Location of fish farms: *1, 2, 3* – farms with flow-through systems; *4, 5, 6* – farms with recirculation aquaculture systems

using feeds of similar composition (Tab. 1). The material consisted of 960 fish, i.e. 40 trout netted in each farm 4 times (terms of material collection is presented in table 2). At the collection point, the fish were killed after anaesthetization, washed, gutted, re-washed, packed into plastic bags and then transported into laboratory in ice. For analysis purposes, samples of muscle tissue (without skin and bones) of 5 cm width were cut out from the middle part of the fillet from the dorsal side to the abdominal side. Each sample was homogenized separately, frozen at -18°C and stored in plastic bags.

Table 1

Feed composition

Producer	Protein	FAT	Carbohydrates	Fibre	Ash
	%				
Agro-Fish	42	24	13.8	2	9
Aller	42	24	17	2	7
BioMar	40	20	18.2	3.8	6.0
Skretting	42	28	–	2.1	6.5

Determination of dry matter content

Dry matter content in rainbow trout muscle tissue was determined according to norm PN-ISO 1442:2000 in triplicates. The reference method on determination of water content in meat and meat products is grounded on drying the mixture of sample and sand at 103 ±2°C up to constant mass.

Statistical analysis

A statistical analysis was conducted using the STAT statistical software package (Statistica, Version 10.0). The average content of dry matter was determined at $p < 0.05$. The homogeneity of variances was examined using Levene's test. Non-parametric analysis (Mann-Whitney U test) was used to determine if there were differences in dry matter content, depending on the farming technology and season of catching. A test of the significance between the number of averages was performed using non-parametric analysis of multiple comparisons of means (Kruskal-Wallis). Spearman correlation coefficients were calculated to determine the strength and significance of the correlation.

Results

The dry matter (DM) content in the muscle tissue of rainbow trout (*Oncorhynchus mykiss* Walbaum) from different farming technologies is presented in Table 2. Fish originating from RAS farms contained from 21.88% to 30.20% of dry matter and trout from FTS technology contained from 21.08% to 31.13%. No correlation between farming technology and dry matter content was found. The season of catching influenced DM, both on farms applying water recirculation and on farms with a flow-through system. The mean dry matter content in the muscles of trout netted in 2011 on RAS farms amounted to 25.95% and was significantly different from results obtained in the other years. Moreover, trout netted in the spring of 2012 in FTS farms contained a significantly higher content of dry matter compared to the fish netted on these farms in the other years.

Table 2

Terms of fish catching

Farm	I	II	III	IV
1	15.12.2010	05.06.2011	09.10.2011	13.05.2012
2	18.12.2010	04.06.2011	16.10.2011	05.05.2012
3	06.12.2010	22.05.2011	08.10.2011	02.06.2012
4	14.11.2010	11.07.2011	13.10.2011	20.05.2012
5	15.11.2010	18.06.2011	28.10.2011	03.06.2012
6	13.11.2010	12.06.2011	23.10.2011	20.05.2012

Table 3

Dry matter content according to the trout farming technology

Technology		RAS		FTS	
		Mean* + SD [%]	Min – Max [%]	Mean* + SD [%]	Min – Max [%]
		25.68 ± 1.335	21.88 – 30.20	25.88 ± 1.566	21.08 – 31.13
Year	2010	25.42 ± 0.978^{a}	23.16 – 29.20	26.08 ± 0.978^{a}	23.30 – 28.28
	2011	25.95 ± 1.422^{b}	21.97 – 30.20	26.11 ± 1.842^{a}	21.08 – 31.13
	2012	25.43 ± 1.369^{a}	21.88 – 29.30	25.21 ± 1.201^{b}	22.65 – 28.46
Season	Autumn	25.26 ± 1.322^{A}	21.88 – 30.20	25.38 ± 1.599^{A}	21.08 – 31.13
	Spring	26.11 ± 1.206^{B}	23.16 – 29.20	26.39 ± 1.402^{B}	23.07 – 30.33

* Values, in columns within the same groups (Technology, Season), marked with different characters are significantly different (p < 0.05).
RAS – recirculation aquaculture systems, FTS -technology with flow-through systems.

The mean content of DM of all the fish netted in autumn was 26.25% (Tab. 4) and was higher than in spring (25.32%). The collection site (farm) influenced DM more strongly in spring than in autumn; significant differences in the dry matter content of fish bred in different farms was found more often in spring than in autumn. The type of fish feed influenced DM content depending on the season of trout netting. There was no difference in DM content in trout netted in spring and fed with Biomar and Aller feed. The lowest (and significantly different) DM content in muscle tissue was determined in autumn in trout fed with Biomar.

In the FTS farms, the year of netting influenced muscle dry matter (-0.23, $p < 0.05$) the most and in the RAS farms it was the season (-0.32, $p < 0.05$) and type of feed (-0.24, $p < 0.05$). In spring, the DM content was slightly, but

Table 4

Dry matter content of trout, depending on the harvest season

Season	Spring		Autumn	
	Mean* + SD [%]	Min – Max [%]	Mean* + SD [%]	Min – Max [%]
	25.32 ± 1.447	21.08 – 31.13	26.25 ± 1.314	23.07 – 30.33
Farm				
1	25.44 ± 1.495^{a}	22.65 – 28.70	26.22 ± 1.424^{abc}	23.07 – 28.90
2	24.56 ±1.655^{bd}	21.08 – 31.13	26.56 ± 1.815^{abc}	23.33 – 30.33
3	26.18 ± 0.995^{ce}	24.05 – 29.35	26.38 ± 0.717*a*	24.74 – 28.23
4	25.19 ± 1.673^{a}	21.88 – 30.20	26.34 ± 1.188^{a}	23.90 – 29.20
5	24.71 ± 0.965^{d}	21.97 – 28.60	25.98 ± 1.346^{b}	23.16 – 28.77
6	25.88 ± 0.905^{e}	22.13 – 28.56	26.00 ± 1.036^{bc}	23.88 – 28.99
Feed				
Agro – Fish	26.53 ± 1.091^{b}	24.11 – 29.35	26.38 ± 0.717^{a}	24.74 – 28.23
Aller	25.18 ± 1.250^{a}	21.97 – 28.60	26.32 ± 1.290^{a}	23.07 – 29.20
BioMar	25.32 ± 1.672^{a}	21.08 – 31.13	25.02 ± 0.773^{b}	23.16 – 27.32
Skreting	25.14 ± 1.422^{c}	21.88 – 30.20	26.43 ± 1.576^{a}	23.20 – 30.33

* Values, in columns within the same groups (Technology, Year, Season), marked with different characters are significantly different ($p < 0.05$).
Agro-Fish, Aller, BioMas, Skreting – trade names of feed.

Correlation analysis confirmed the abovecorrelations between dry matter content and rainbow trout farming technology (Tab. 5). Regardless of farming technology, the most significant influence on DM content was the netting season (-0.31, $p < 0.05$). Farming technology did not influence DM content in trout muscle tissue. The year of sampling and feed type showed a small, yet statistically significant, correlation with dry matter (respectively, 0.10, -0.12, $p < 0.05$). No correlation was calculated between place (farm) of netting and DM content.

Table 5

Correlation of the dry matter content in trout depending on the technology and culture conditions

	Technology	Year	Season	Farm	Feed
Technology	0.07*	-0.10*	-0.31*	-0.01	-0.12*
RAS	–	0.03	-0.32*	0.06*	-0.24*
FTS	–	-0.23*	-0.30*	0.16*	-0.13*
Season					
Spring	0.07*	0.00	–	0.05*	0.00
Autumn	0.08*	0.38*	–	-0.08*	-0.17*
Farm					
1	RAS	-0.33*	-0.23*	–	0.24*
2	RAS	-0.11*	-0.53*	–	-0.14*
3	RAS	-0.32*	-0.12*	–	-0.31*
4	FTS	-0.04	-0.38*	–	-0.38*
5	FTS	-0.03	-0.48*	–	-0.10*
6	FTS	0.20*	-0.06	–	–

* Statistically significant correlations ($p < 0.05$).
RAS – recirculation aquaculture systems, FTS – technology with flow-through systems.
Aqua – Fish, Aller, Biomas, Prima-Skreting – trade names feed.

significantly, correlated with farming technology (0.07, $p < 0.05$) and also with the place of netting (0.05, $p < 0.05$). In autumn, the DM content was clearly significantly correlated with the year of trout sampling (0.38, $p < 0.05$), but only was only slightly significantly correlated with the other parameters.

Discussion

It is well-known that the content of dry matter depends on fish species. For example, POLAK-JUSZCZAK (2007) determined the DM content in various fish species: 39.68% – butter fish, Nile perch – 20.70%, African wels – 24.47%, panga – 17.18%. GRELA et al. (2010) found 21.6% of DM in carp meat, 20.39% in pike and 20.43% in zander. The authors stated that the content of nutrients depended on fish species, although they observed a tendency to increase DM content in the meat of carp and bream with netting prolongation. HARTMAN and MARGRAF (2008) found general relationships between the contents of dry matter and fat and protein, and suggested using the water content determination as a simple and economical predictor of body percent composition of rare species of fish.

The presented results of DM content in rainbow trout are similar to those reported by other authors. SKAŁECKI et al. (2013) determined DM content in rainbow trout from farms located in Lubelskie; the content was significantly different: 22.7% in fish of assortment S (fish of 350 – 500 g) and 25.4%

– D (501 – 800 g). The value of this parameter increased with fish size. WEATHERUP and MCCRACKEN (1999) also found a significant increase in DM content with trout age. TKACZEWSKA and MIGDAŁ (2012) analyzed samples of trout netted in fish farms situated in 4 regions of Poland (Malopolskie, Śląskie, Świetokrzyskie and Warmińsko-Mazurskie) and determined DM in a wide range (from 23.41% to 28.93%), depending on the farming system. SZCZEPANIK et al. (2011) analyzed changes in trout meat occurring during refrigeration storage; the dry matter content of trout bought in the Zachodniopomorskie provincial market (fresh fish stored in ice) amounted to 21.19%.

ÖZDEN (2005) determined 23.77% of DM in trout meat (*Salmo gairdneri*) bought at a market in Istanbul. UNUSAN (2007) analyzed trout originating from the Konya region, Turkey, located in the middle of Anatolia, netted in September, 1997. The mean dry matter content amounted to 28.71%. FALLAH et al. (2011) found from 24.92 to 26.08% of dry matter in meat of farmed trout and from 21.05 to 22.15% in wild ones. The authors concluded that the differences between farmed and wild fish DM contents resulted from fish diet composition and the environmental conditions of fish life.

Several works have confirmed the influence of trout feeding on dry matter content in fish meat. A feeding experiment was conducted by KENNETH et al. [2004] using four experimental feeds containing fats of different origin. At the beginning of the experiment, trout fillets contained 26% of dry matter and after 16 weeks this increased to 37-39% due to a considerable increase in both the protein and fat contents (the latter component doubled). GÜMÜŞ and YKIZ (2009) fed trout for 13 weeks with 4 diets equal in proteins and energy and different in carbohydrates and fats. The content of DM decreased with a decreased fat content (from 25.8 to 23.9%).

ZOCCARATO et al. [1994] conducted a twelve-week experiment to assess trout fillet composition depending on nutrition and fish density in pond. The dry matter content amounted to: 23.64 ±0.39% at low density and high feeding level (the highest results), 23.44 ±0.75% at high density and high feeding level, 22.74 ±0.67% at low density and low feeding level and 22.59 ±0.10% at high density and low feeding level. TURCHINI et al. (2004) proved that farming trout in an extensive system (rich fish community, not granulated feed) increased the general quality of the fish by improving the content and composition of fish fatty acids. HUNG and STOREBAKKEN (1994) proved that DM content in trout fillet fed continuously was lower than in fish fed four meals daily.

OO et al. (2007) showed that replacement of fish oil in trout fed by palm oil did not disturb fish growth but lowered dioxin contamination in trout fillet. SHAFAEIPOUR et al. (2008) also confirmed that applying plant oil (canola oil) instead of fish meal in rainbow trout feed did not affect the fish growth performance and could be successfully used in trout feed production. DEFRAN-

CESCO et al. (2004) did not find significant differences in DM contents in fillets of trout fed with fish meal addition (28%) and a mixture of plant protein sources (27%).

Conclusions

1. Farming technology did not influence the content of dry matter in the rainbow trout muscle tissue.
2. The season of fish netting significantly influenced the dry matter content; the content of dry matter in muscles of rainbow trout netted in autumn was higher than those collected in spring.
3. The place of netting (farm) more strongly influenced dry matter content in spring than in autumn.
4. The dry content of matter in muscles of fish caught in autumn significantly depended on kind of feed used for fish feeding.

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