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Influence of farming technology on bioaccumulation of calcium, magnesium and sodium in muscle tissue of rainbow trout (*Oncorhynchus mykiss* Walbaum)

Wpływ technologii chowu na biokumulację wapnia, magnezu i sodu w tkance mięśniowej pstrąga tęczowego (*Oncorhynchus mykiss* Walbaum)

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Słowa kluczowe: jakość wody, system chowu ryb, system przepływowy, system recyrkulacji, biokumulacja, składniki mineralne

Abstract
Poland is one of the countries with limited water resources where water saving is recommended e.g. by improving aquaculture methods to use less water. The aim of the study was to determine the influence of water quality and aquaculture technology on bioaccumulation of calcium, magnesium and sodium in muscle tissue of rainbow trout. The study was performed in spring and autumn 2011 in two trout fish farms using different farming technologies: one with flow-through system and the other with water recirculation system. The farming technology had significant influence on magnesium and sodium in waste waters but did not affect the content of the minerals in muscle tissue of rainbow trout.

Streszczenie
Polska należy do krajów o ograniczonych zasobach wodnych, w których wskazana jest oszczędność wody m.in. poprzez doskonalenie metod produkcji rybackiej o zmniejszonym zużyciu wody. Celem pracy było określenie wpływu jakości wody oraz technologii chowu na biokumulację wapnia, magnezu i sodu w tkance mięśniowej pstrąga tęczowego. Badania przeprowadzono wiosną i jesienią 2011 roku w 2 gospodarstwach pstrągowych z województwa pomorskiego stosujących odmienne technologie chowu: z jednokrotnym przepływem wody oraz z systemem recyrkulacji wody. W badanych obiektach technologia chowu miała istotny wpływ na stężenie magnezu i sodu w wodach odpadowych, natomiast nie miała wpływu na zawartość badanych metali w tkance mięśniowej pstrąga tęczowego.

1. INTRODUCTION

Technology of farming and conditions of salmonid production influence not only quality of the meat but also affect environmental chemical and biological indexes [Sidoruk 2012]. Choosing the optimal method of water management in trout production, one should consider not only profitability of production but also influence of the technology on the natural environment. Intensive development of freshwater fish aquaculture technologies and need to protect water resources forced the improving of waste waters cleaning [Colt 2006, Kristensen et al. 2009]. In countries of limited water resources, rational use of water becomes a priority.

Intensive fish farming technology is accompanied with increase of waste water volume. Trout bred intensively are kept in considerable density leading to water contamination with fish metabolites and also with residues of uneaten feed. Great density of fish causes increase of water contamination and oxygen deficits [Davidson et al. 2009, Sindilariu 2007]. The aim of the work was to determine the influence of farming technology and water quality on calcium, magnesium and sodium bioaccumulation in muscle tissue of rainbow trout.

2. MATERIAL AND METHOD

The study was performed in spring and autumn 2011. Two trout fish farms in Pomerania voivodeship have been selected. The farms used different systems of water management: one produced fish with flow-through system (FTS) and the other with water recirculation (RAS – Recirculating Aquaculture System). All the fish farms under the study applied feeds of similar composition. Samples of inflow water to the farm, water flowing out of the trout ponds and flowing out of the farm after passage in the cleaning lagoon were analysed in triplicates.

Segments of about 5 cm of muscle tissue of rainbow trout, without skin and bones, was cut off the middle part of fillet from dorsal to abdominal side for chemical analysis. Samples of 40 fish were collected in each of the farms. Content of calcium, magnesium and sodium in water and fish samples were determined by atomic absorption spectrometry.

The results were analysed statistically (Statistica 10, StatSoft-Kraków) using Tukey's test and correlation analysis was performed to assess the dependence of metal bioaccumulation in muscle tissue on farming technology and water quality.

3. RESULTS AND DISCUSSION

Calcium and magnesiumare the water components that, together with bicarbonates and sulphates, define hydrochemical type of majority of surface waters. In temperate climate, both biogens are intensively washed away from the agricultural soils, which is promoted by acidification of downfalls. Suitable high concentrations of Ca^{2+} and Mg^{2+} in water are important for buffering purposes and are essential to primary production securing enough CO_2 for photosynthesis [Koc et al. 2009]. Usually, considerable lower concentrations of magnesium in comparison with calcium are determined, probably due to intensive intake of the element by plants and concentration in atmospheric downfalls [Koc, Sidoruk 2013].

In the inflow water entering the farm, average calcium concentration was rather low and during the whole period of the study did not exceed norms for class I of water quality [Rozporządzenie 2011]. In FTS farm, Ca^{2+} concentration in inflow water amounted to 50.9 mg/dm^3 in spring and 57.5 mg/dm^3 in autumn, and in the farm using recirculated water 52.1 mg/dm^3 in spring and 55.6 mg/dm^3 in autumn (Fig. 1). A small increase in calcium concentration in water flowing out of the FTS farm ponds was observed in spring. After passing the water from the ponds through cleaning lagoon, a very small reduction of calcium concentration in water flowing out of the RAS farm was observed and in FTS farm positive activity of the lagoon was observed only in autumn; in spring, a slight increase of the element concentration was found.

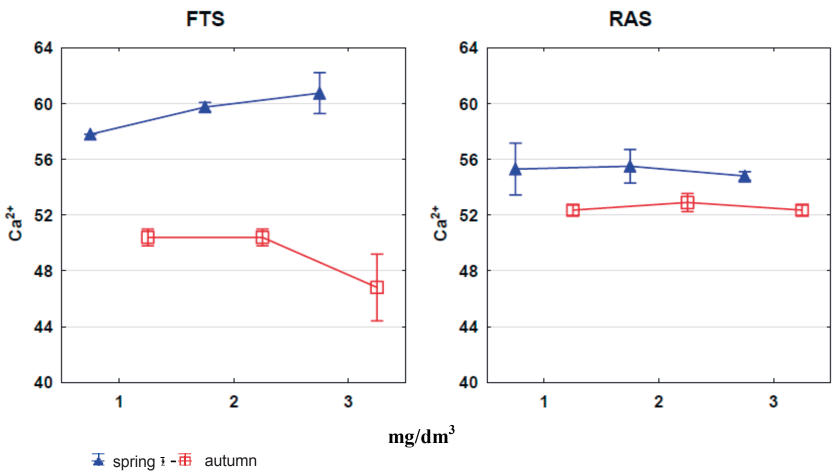
Concentrations of magnesium in inflow water to FTS farm amounted to 7.8–8.1 mg/dm^3 and 5.6–6.4 mg/dm^3 in the RAS farm (Fig. 2). Different geologic and soil conditions existing in drainage area of river supplying the farm might be the reason. As a result of using the water for fish farming, an increase by about 6% of magnesium concentration was observed in pond water of the FTS farm in both seasons. Positive activity of cleaning lagoon by 6–8% was confirmed in this farm. In the RAS farm, a slight increase of magnesium concentration in the pond water to the level of 5.9 mg/dm^3 was found in spring but in autumn the concentration dropped by about 14%. In this farm, efficiency of lagoon activity depended on the season: a slight increase in spring and decrease in autumn.

Cations of sodium, similar to calcium, appear commonly in surface waters. Sodium may originate from soluble evaporates and anthropogenic contamination, but sodium minerals are its general source [Bonisławska et al. 2011].Content of sodium in inflow water was low in both farms and amounted to 7.2–8.8 mg/dm^3 in FTS farm and 5.2–7.1 mg/dm^3 in RAS farm during the whole experimental time (Fig. 3).

In both farms, a slight increase in sodium concentration in pond water was observed in spring. In autumn, Na^+ concentration dropped a little in water of FTS farm and no change was determined in RAS farm. A slight increase of sodium concentration in outflow was observed in FTS farm in both seasons and in RAS farm in autumn and a small decrease of Na^+ concentration as a result of passing water through lagoon was determined in RAS farm in spring.

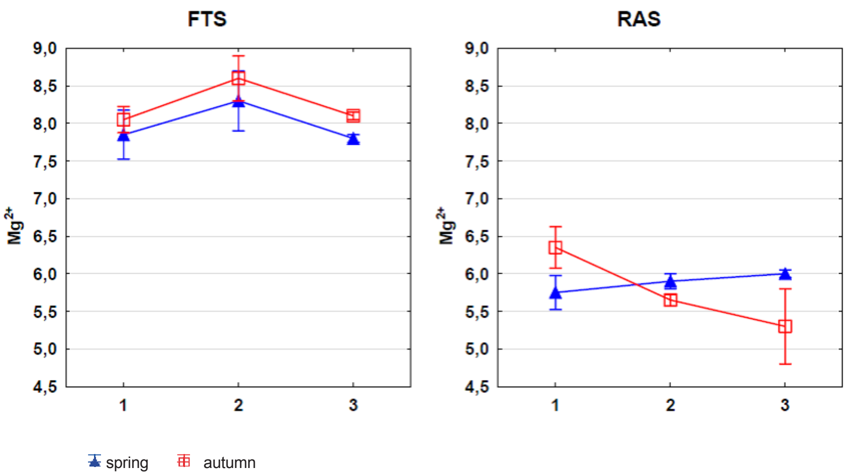
Farming technology significantly influenced magnesium and sodium content in the water (Table 1). Magnesium content in water very highly correlated with farming technology, while sodium content moderately correlated with farming technology and season of sampling. Farming technology had no influence on calcium concentration in water. Ca^{2+} concentration was highly dependent on sampling season. Point of sampling did not influence the concentration of the metals in water.

The use of technology of water management in freshwater aquaculture and influence of production system on natural environment create both water and fish meat quality. Fish meat quality depends mostly on content of nutrients, including minerals, in feed [Martins et al. 2009]. The content of calcium and sodium in muscle tissue of rainbow trout varied significantly with dependence on netting season (Table 2). Dependence of the applied farming technology on the metals content in muscle tissue was not confirmed statistically. Conditions of fish farming and water quality decide bioaccumulation of metals in the fish muscles [Baldisserotto et al. 2005]. The farm production technology did not influence bioaccumulation of calcium, magnesium and sodium in trout muscle tissue (Table 3). Netting season determined significantly bioaccumulation of metals in trout muscles: low correlation for magnesium and moderate for calcium and sodium. Moderate correlation between calcium bioaccumulation in muscles and concentration of the metal in water was proved. Also, high correlation between Ca concentration in muscles and Na in water was calculated. Bioaccumulation of sodium in trout muscle was moderately correlated with Ca and Na concentration in water. Water quality and quantity of metals in it significantly influenced bioaccumulation of the metals in rainbow trout muscle tissues. Comparing mean values of the metal concentrations in water and in muscle tissue of the fish, one can



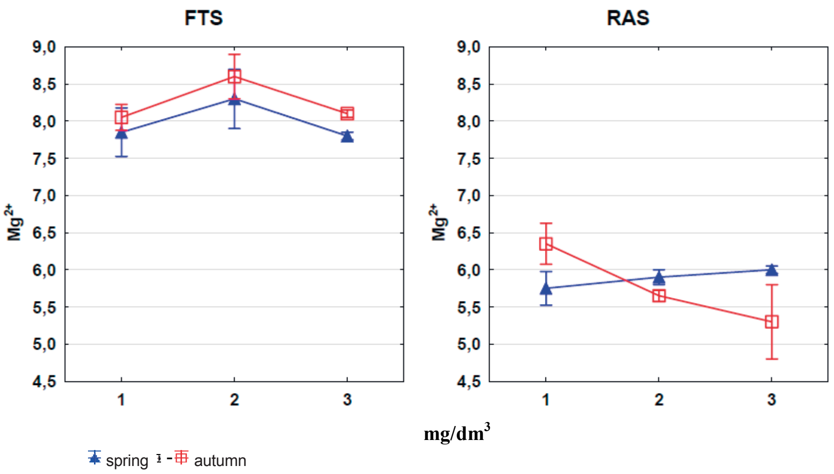
1 – inflow to the farm, **2** – outflow from the ponds, **3** – outflow from the farm, after the clearing lagoon

Fig. 1. Concentration of calcium (mean ± SEM) in water of farm producing trout with flow-through system (FTS) and water recirculation (RAS)



1 – inflow to the farm, **2** – outflow from the ponds, **3** – outflow from the farm, after the clearing lagoon

Fig. 2. Concentration of magnesium (mean ± SEM) in water of farm producing trout with flow-through system (FTS) and water recirculation (RAS)



1 – inflow to the farm, **2** – outflow from the ponds, **3** – outflow from the farm, after the clearing lagoon

Fig. 3. Concentration of sodium (mean ± SEM) in water of farm producing trout with flow-through system (FTS) and water recirculation (RAS)

Table 1. Spearman's indexes of correlation of metal concentration in water and farming technology

Element	Technology	Season	Sampling point
Ca^{2+}	0.00	-0.78*	0.05
Mg^{2+}	-0.87*	0.07	-0.02
Na^{+}	-0.54*	-0.60*	0.05

*Spearman correlation indexes significant by $p<0.05$ (<0.2 – weak correlation, 0.2–0.4 – low correlation, 0.4–0.6 – moderate correlation, 0.6–08 – high correlation, 0.8–0.9 – very high correlation, 0.9–1 – full correlation).
Technology – farming technology (FTS, RAS); Season – netting season (spring, autumn); Point – point of water sampling (inflow to ponds, outflow from ponds, and outflow from the farm).

Table 2. Content of metals in muscle tissue of rainbow trout

Parameter		Ca	Mg	Na
		Mean ± SEM [mg/kg]		
Mean		302±25.8	312±5.2	460±17.6
Technology	FTS	305±45.1a	303±17.3a	450±43.1a
	RAS	300±31.7a	316±2.5a	464±18.1a
Season	spring	394±37.2A	309±3.5A	563±11.5A
	autumn	247±31.6B	314±8.1A	398±21.4B

* Mean values in columns (Technology, Season) marked with the same letters do not vary significantly at $p<0.05$.

Table 3. Spearman's indexes of correlation between metal concentration in muscle tissue of rainbow trout and farming technology and water quality

Element	Technology	Season	Ca^{2+}	Mg^{2+}	Na^{+}
Ca	-0.04	0.41*	0.42*	-0.09	0.70*
Mg	-0.23	-0.34*	0.02	0.28	0.19
Na	-0.02	0.57*	0.56*	-0.02	0.54*

* Spearman correlation indexes significant by $p<0.05$ (<0.2 – weak correlation, 0.2–0.4 – low correlation, 0.4–0.6 – moderate correlation, 0.6–08 – high correlation, 0.8–0.9 – very high correlation, 0.9–1 – full correlation).
Technology – farming technology (FTS, RAS); Season – netting season (spring, autumn); Ca^{2+}, Mg^{2+}, Na^{+} – concentration of metals in water.

conclude that fish accumulate high amounts of the metals in their meat in comparison with the content in water (Fig. 4). Sodium was the element accumulated in the trout muscles to the highest extent (about 450%).

4. CONCLUSIONS

1. Concentration of calcium, magnesium and sodium in inflow water was low and during the whole experimental period did not exceed norms of the class I of water quality.
2. Technology of water management influenced significantly concentration of magnesium and sodium in water flowing out of the farms. Very high correlation between concentration of magnesium and moderate concentration of sodium in water and fish farming technology was calculated.
3. Farming technology did not influence the content of calcium, magnesium and sodium in muscle tissue of rainbow trout.

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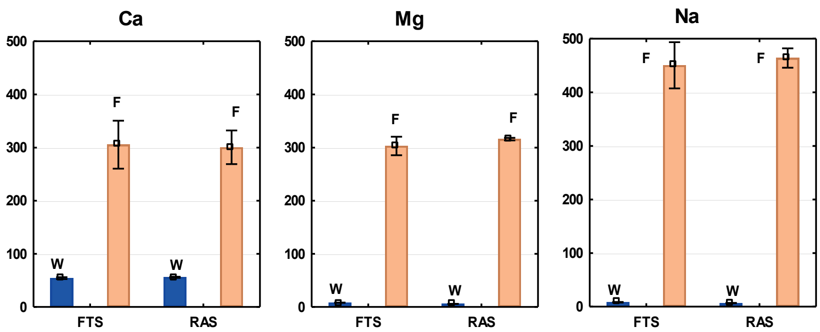

W – concentration in water [mg/dm³], F – concentration in fish muscle tissue [mg/kg⁻¹] RAS – recirculation aquaculture systems, FTS – technology with flow-through systems

Fig. 4. Mean concentration (mean ± SEM) of calcium, magnesium and sodium in water and in muscle tissue of rainbow trout

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