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# The influence of intensive fish nutrition on the quality of cooling waters

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**Key words:** carp, cooling waters, extruded fish feed, water quality

## Abstract

The aim of the present paper is to present the results of a study on the impact intensive carp (*Cyprinus carpio* L.), feeding with extruded commercial feed has on the quality of cooling waters. The feed studied had varied fat and carbohydrate contents. The study also revealed the optimal hydrochemical conditions of cooling waters for carp farming. Cage farming caused growing loads of organic matter, nitrogen, and phosphorus in the water. Experimental extraction of feed from the water revealed that high fat fish feed was more stable in comparison to high carbohydrate fish feed. Intensive carp farming with these two feeds led to considerable fish weight gain in both feed groups, but the weight gain for the carp fed with high fat feed, in comparison with that of carp fed with high carbohydrate fish feed, was significantly greater ($p<0.01$).

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## INTRODUCTION

Aquaculture is growing, and it is estimated that by 2010 will reach a level of about 40 million tons (FAO). Fish farming is based mainly on properly balanced fish feed compounds. This renders it possible for fish to attain fast individual body weight growth and good condition. Intensive fish farming carries the risk of water pollution from the decomposition of unconsumed feed as well as the products of fish metabolism (Lewkowicz and Lewkowicz 1976, Karakassis et al. 1999, Pereira et al. 2004).

Carp (*Cyprinus carpio* L.) is one of the most frequently cultivated fish. Apart from its role in the culinary tradition, its economic importance is dictated by its ability to adjust to changeable environmental conditions (water quality and diverse fish feed components), and it has a high feed conversion ratio (Jauncey 1982).

The aim of the present paper is to determine the quality of cooling waters during intense feeding of carp (*Cyprinus carpio* L.) with extruded commercial feed. The fish feed examined had varied fat and carbohydrate compositions. Additionally, laboratory studies of the evaluation of the release of nutritive compounds of fish feed during water extraction were carried out.

## MATERIALS AND METHODS

Cage farming of carp (individual initial weight 170 ±5 g) was conducted for seven weeks (May-June 2003) at the Experimental Fisheries Station (RSD), Department of Aquaculture, Agricultural University of Szczecin, located on the grounds of the Lower Oder Power Station in Nowe Czarnowo (northwest Poland). The fish were divided randomly into two feeding groups, and 50 fish were placed into six cages measuring of 2.0 × 0.75 × 0.8 m with a capacity of 1.0 $m^3$. The cages were placed 250 m below the cooling water discharge from the power station. The fish were fed feed with different compositions of fat and carbohydrates (i.e., high fat and high carbohydrate fish feed (Table 1)). The feed was administered daily between 8:00 am and 3:00 pm at a frequency of every 90 minutes. The daily food ration was 2% of the fish stock weight (Sadowski 1998). To estimate cultivated fish weight and to adjust the feed ration, the fish were weighed every seventh day. The findings were analyzed statistically using single factor variance and the LSD test (StatSoft Inc. 1995). Throughout the experiment the water temperature, concentration of dissolved oxygen, and pH were monitored (Table 1).

During the experiment, a detailed hydrochemical analysis was carried out. Water samples were taken from inside the cages, in front, and at the back of them12 hours after the last feeding (Table 2). In order to estimate the influence

**Table 1**

The range of values variations of selected hydrochemical factors in the studied waters.

| | Temperature | Dissolved oxygen | pH |
|---|---|---|---|
| | °C | $mgO_2\ dm^{-3}$ | |
| Minimum | 17.0 | 3.0 | 7.6 |
| Maximum | 26.6 | 11.4 | 9.7 |
| Mean | 18.5 | 8.5 | 8.2 |

**Table 2**

Average hydrochemical rate values in cooling waters in front of cages (A), in cages where high fat feed was administered (B), high carbohydrate (C) and at the back of cages (D) taken 12 hours after the last feed ration was administered.

| Factor[a] | A | B n=3 | C n=3 | D |
|---|---|---|---|---|
| Conductivity | 612.0 | 623.3 | 621.3 | 622.0 |
| pH | 8.66 | 8.59 | 8.58 | 8.60 |
| Nitrite nitrogen | 0.026 | 0.029 | 0.032 | 0.025 |
| Nitrate nitrogen | 0.077 | 0.079 | 0.079 | 0.073 |
| Ammonium nitrogen | 0.092 | 0.093 | 0.107 | 0.087 |
| Total nitrogen | 0.706 | 0.724 | 0.877 | 0.735 |
| Reactive phosphorus | 0.047 | 0.058 | 0.061 | 0.092 |
| Total phosphorus | 0.267 | 0.271 | 0.274 | 0.270 |
| $COD_{Cr}$ | 54.0 | 59.2 | 59.3 | 58.0 |
| Sulfate ions | 52.3 | 52.8 | 51.4 | 50.6 |
| Chlorides | 127.8 | 117.2 | 119.4 | 113.6 |
| Total suspended matter | 72.0 | 49.7 | 52.3 | 42.0 |
| Dissolved substances | 418.0 | 437.0 | 455.7 | 448.0 |
| Chlorophyll *a* | 256.3 | 233.1 | 260.6 | 239.2 |

[a] units: conductivity in $\mu S\ cm^{-1}$; alcalinity in $mval\ dm^{-3}$; $COD_{Cr}$ in $mgO_2\ dm^{-3}$; chlorophyll *a* in $mg\ m^{-3}$; others in $mg\ dm^{-3}$

of the fish feed, samples of water were taken directly before and after the three subsequent feedings administered at 1 hour intervals (Table 3).

An experiment was conducted under laboratory conditions to estimate the release of nutrients from the fish feed into the water. Feed samples weighing 10 ±1 g were subjected to extraction with distilled water (water capacity 1 $dm^3$) at 20°C. The water samples used for hydrochemical analysis were taken at the beginning of extraction and after 10 and 60 minutes. Water deficits (about 0.2 $dm^3$) were compensated for every time with fresh distilled water (Fig. 1, 2). Organic matter (CODCr), nutrients (ammonia nitrogen, nitrate nitrogen, total nitrogen, total phosphorus, reactive phosphorus), alkalinity, sulfate ions, chloride, dry residue, total suspended matter, dissolved substances, conductivity, and chlorophyll *a* were determined according to Standard Methods (1995).

**Table 3**

Variability of marked hydrochemical rates in cages before and after serving three subsequent high fat and high carbohydrate feed rations.

| Factor[a] | High fat feed | | | | High carbohydrate feed | | | |
|---|---|---|---|---|---|---|---|---|
| | Before serving feed | I serving feed | II serving feed | III serving feed | Before serving feed | I serving feed | II serving feed | III serving feed |
| Conductivity | 586.0 | 588.0 | 599.0 | 597.0 | 581.0 | 588.0 | 602.0 | 594.0 |
| pH | 8.23 | 8.33 | 8.24 | 8.05 | 8.28 | 8.38 | 8.22 | 8.11 |
| Nitrite nitrogen | 0.023 | 0.017 | 0.016 | 0.015 | 0.017 | 0.019 | 0.021 | 0.019 |
| Nitrate nitrogen | 0.073 | 0.074 | 0.081 | 0.077 | 0.076 | 0.081 | 0.078 | 0.086 |
| Ammonium nitrogen | 0.104 | 0.097 | 0.123 | 0.189 | 0.105 | 0.091 | 0.123 | 0.191 |
| Total nitrogen | 0.427 | 0.404 | 0.496 | 0.415 | 0.390 | 0.514 | 0.462 | 0.470 |
| Reactive phosphorus | 0.049 | 0.058 | 0.050 | 0.054 | 0.046 | 0.046 | 0.073 | 0.071 |
| Total phosphorus | 0.169 | 0.153 | 0.179 | 0.239 | 0.269 | 0.276 | 0.268 | 0.289 |
| $COD_{Cr}$ | 22.0 | 43.6 | 30.8 | 30.8 | 28.8 | 34.0 | 32.0 | 32.2 |
| Total alcalinity | 2.1 | 2.2 | 2.0 | 2.2 | 2.3 | 2.1 | 2.3 | 2.3 |
| Sulfate ions | 26.7 | 26.9 | 27.6 | 21.5 | 28.2 | 29.7 | 23.6 | 19.4 |
| Chlorides | 95.9 | 99.4 | 99.4 | 103.0 | 95.9 | 103.0 | 106.5 | 99.4 |
| Total suspended matter | 29.0 | 34.0 | 34.0 | 18.0 | 39.0 | 27.0 | 22.0 | 22.0 |
| Dissolved substances | 449.0 | 410.0 | 428.0 | 470.0 | 377.0 | 443.0 | 458.0 | 508.0 |
| Chlorophyll *a* | 162.5 | 137.5 | 136.0 | 197.3 | 113.6 | 195.9 | 130.1 | 149.5 |

[a] units: conductivity in $\mu S\ cm^{-1}$; alcalinity in mval $dm^{-3}$; $COD_{Cr}$ in $mgO_2\ dm^{-3}$; chlorophyll *a* in mg $m^{-3}$; others in mg $dm^{-3}$

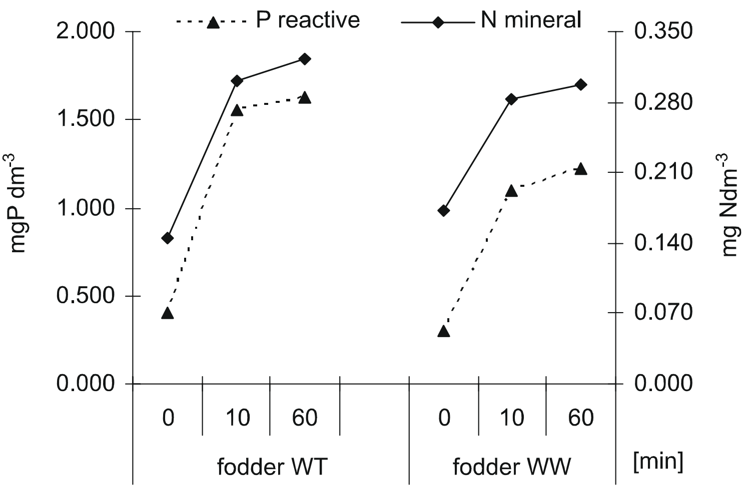


**Fig. 1.** Dynamics of reactive phosphorus and mineral nitrogen release from high fat feed (feed WT) and high carbohydrate feed (feed WW).

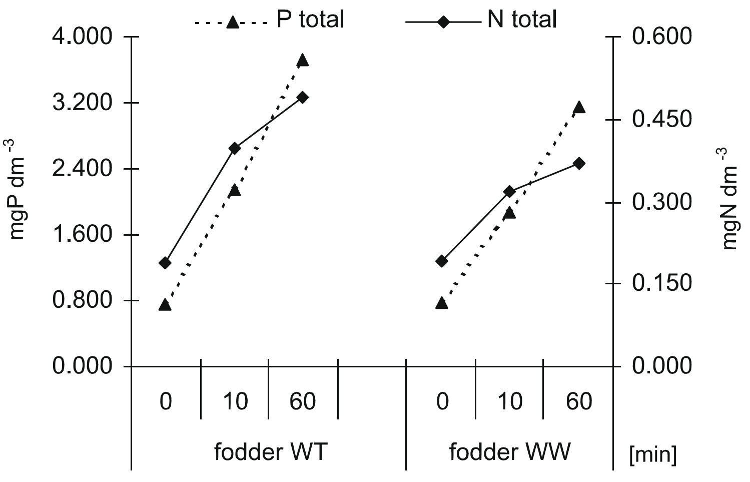


**Fig. 2.** Dynamics of total phosphorus and total nitrogen release from high fat feed (feed WT) and high carbohydrate feed (feed WW).

## RESULTS AND DISCUSSION

Carp is a thermophilic fish and it attains considerable body weight growth in waters at temperatures above 20°C (Jauncey 1982, Steffens 1986, Zimmerman 2003). During the study, the water temperature fluctuated from 17 to 22.8°C. Simultaneously, the waters were well oxygenated (from 5.5 to 9.6 $mgO_2\,dm^{-3}$) and well buffered (total alkalinity exceeded 2 mval $dm^{-3}$ (Tables 2-3). These conditions were favorable for fry and carp growth (Dickson 1983, Brylińska 1991), and the pH was slightly higher than that presented by Filipiak and others (1995) and was most favorable for carp farming (Tables 1-3).

The salinity of the cooling waters, defined as dissolved substances, was two times higher than the average salinity of Polish surface waters, reported by Korycka (1989) to be 260 mg $dm^{-3}$ (Table 3). As stated by Zimmerman (2003) and Thorman (1986), the most significant factor for fish (especially for spawn and hatchlings) is water salinity. Higher water salinity recorded in the examined waters was typical for the estuarine part of the Oder River and did not have any negative influence on carp growth. Total suspended matter noted there fluctuated within the range proposed by Buck (1956) as optimal to keep production at a good level (Tables 2, 3).

The load of organic matter in the studied cooling waters was higher than that noted by Tórz (2002) in the waters of the Eastern Oder, which indicates the indigenous origin of the organic matter. In addition, an increase of organic matter in the cages was noted in comparison with the samples taken from in front of the cages. In particular, high increases of the load of the organic matter was noted in the cages immediately after the three subsequent fish feedings (average 12 $mgO_2\ dm^{-3}$ in proportion to the concentration before feeding) (Table 3). In the water samples taken 12 hours after the last feeding, the rise of $COD_{Cr}$ value averaged 5 $mgO_2\ dm^{-3}$ (Table 2).

The waters of the Oder River in the vicinity of the cooling water intake are rich in nutrient elements. The concentrations of mineral nitrogen generally exceeded by two fold the values stated by Meybeck (1982) as natural for waters not subjected to human impact. Furthermore, the slightly dominant form in the examined waters was ammonium nitrogen (Tables 2, 3). The rather balanced relationship of oxidized and reduced species of nitrogen noted in the study indicate there is a very intensive process of nitrification. The considerably fast return of nitrates to the depths contributes to the increasing concentration of chlorophyll *a* that was noted (Tables 2, 3) (Januszkiewicz et al. 1977, Heip et al. 1995, Rabalais 2002). Among nitrogen and phosphorus forms, organic nitrogen and organic phosphorus were prevalent comprising about 70% of the total nitrogen and almost 80% of the total phosphorus (Table 2).

Greater increases in the concentrations of nitrogen and phosphorus were noted during the study in the cages than in the samples taken in front of the cages; in particular, there was a high increase (despite a 12-hour period without feeding) in total nitrogen (0.018 $mgN\ dm^{-3}$ for high fat feed and of 0.171 $mgN\ dm^{-3}$ for high carbohydrate fish feed) and for orthophosphates (close for both fish feeds at about 0.013 $mgP\ dm^{-3}$) (Table 2). In the samples taken straight after feedings there were notable increases in the concentrations of ammonia nitrogen (average of 0.030 $mgN\ dm^{-3}$ for both feed types); total nitrogen (about 0.011 $mgN\ dm^{-3}$ for high fat feed and 0.092 $mgN\ dm^{-3}$ for high carbohydrate feed); orthophosphates (0.005 $mgP\ dm^{-3}$ and 0.017 $mgP\ dm^{-3}$, for fat- and carbohydrate-rich feeds, respectively), and total phosphorus at 0.021 $mgP\ dm^{-3}$ (Table 3).

The data obtained indicate the generally higher stability of high fat feed in cooling waters in comparison with high carbohydrate fish feed. This is also confirmed by the nutrient emission data from the feed manufacturers (Table 4). Dissimilar results were obtained from the experimental extraction of feed with distilled water. Higher nutrient emission was noted with high fat feed (Fig. 1, 2). Only at the very moment when the feed was placed into the distilled water was there a higher concentration of the analyzed nutrients with the high carbohydrate feed. This is evidence of a necessary shift in the technology toward using high fat feed (which produces high breeding rates) to reduce the time the feed is in the water and to facilitate fast consumption by fish.

**Table 4**

Total nitrogen and total phosphorus emission (according to feed manufacturer data) to water after calculating it according to fish weight in cages (kg $cage^{-1}$) (Group 1 - high fat feed, Group 2 - high carbohydrate feed).

| Nutrient compounds | Group 1 | Group 2 |
|---|---|---|
| Nitrogen | 0.666 | 0.888 |
| Phosphorus | 0.015 | 0.056 |

The current research indicated that intensive carp farming using higher fat feed (group 1) or carbohydrates (group 2), caused intensive body mass growth of the carp of both dietary groups. Besides, growth was highly significant ($p<0.01$) for the fish fed with the high fat feed in comparison to the carp which were fed with the high carbohydrate fish feed (Table 5). This requires that producers use feed with a strictly fixed composition as well as optimal doses (Table 6). Optimal feed will contribute to the physiological functions of the fish and will result in intense body mass growth. Rations that are too high are wasted by the fish and, due to food retention and its decay, can contribute to the increased nutrient content in the water. This phenomenon, in addition to its disadvantageous impact on the environment, does not have any economic rationale.

**Table 5**

Body weight growth of carp (g) fed with high fat feed (Group 1) and high carbohydrate feed (Group 2).

| Before experiment (a) | After experiment | | Significance of differences |
|---|---|---|---|
| | Group 1 (b) | Group 2 (c) | |
| 170.0 ±5 | 450.0 ±10 | 414.0 ±10 | a - b**, a - c**, b - c** |

**Difference significant at *P*≤0.01

**Table 6**

Composition of feeds used in the experiment according to manufacturer data (%), Group 1 - high fat fish feed, Group 2 - high carbohydrate fish feed.

| Component | Group I | Group II |
|---|---|---|
| Protein | 44.0 | 45.0 |
| Lipids | 31.0 | 15.0 |
| **Carbohydrates** | 11.0 | 21.0 |
| Ash | 8.0 | 8.0 |
| Fiber | 1.0 | 2.5 |

## CONCLUSIONS

The study indicated that cooling waters were characterized by optimal hydrochemical conditions for carp farming. Cage farming, despite intensive water flow in the cooling water canal, caused increased organic matter loads of nitrogen and phosphorus in these waters. The source of the nutrients was fish feed as well as the products of cultivated fish metabolism. The differences in the release of nitrogen and phosphorus from the applied fish feed indicated that the technology should be adjusted to the high fat feed (which produced high production indices) due to the short period it is in the water and its quick consumption by the fish.

The study also indicated that the body weight growth of the carp fed with the higher fat feed was intense. Essential roles in intensive fish farming are played not only by the composition of the fish feed, but also by the food ration calculated based on the weight of the fish stock.

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