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RESEARCH ARTICLE

# Dry diet-influenced growth, size variability, condition and body deformities in juvenile crucian carp *Carassius carassius* L. reared under controlled conditions

**Leszek Myszkowski, Rafał Kamiński, Manuel Quiros, L. Andrzej Stanny, Jacek Wolnicki**

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**Abstract**. The growth, size variability, condition coefficient and percentage of fish with external deformities were compared in juvenile crucian carp (initially 31 mm TL and 0.36 g BW) which were fed intensively four starters only for 120 days at 25°C. The best weight gain was achieved by fish fed an experimental carp diet with the lowest fat content (7.4%) and a commercial diet for eel containing 15.9% fat (4.33 and 4.15 g BW, respectively). In contrast to the experimental diets, both commercial diets produced fish with high condition coefficient values and a very high (37.2 or 62.7%) percentage of individuals with different external deformities. Size variability did increase over the course of the experiment except in the fish fed the high-energy diet for eel. Survival rates ranged between 96.5 and 99.5%. Our results indicate that juvenile crucian carp can be successfully reared exclusively on dry diets but not the commercial ones for eel or carp used in the present experiment.

**Keywords:** *Carassius carassius*, juveniles, dry diets, growth, survival, size variability, condition coefficient, body deformities

L. Myszkowski [✉], R. Kamiński, J. Wolnicki
Inland Fisheries Institute in Olsztyn, Poland

M. Quiros
Departamento de Producción Animal, Escuela Técnica Superior de Ingenieros Agrónomos, Universidad Politécnica, Madrid, Spain

L.A. Stanny
Institute of Ichthyobiology and Aquaculture, Polish Academy of Sciences, Poland

## Introduction

Long-term controlled rearing of cyprinid fish through their juvenile stages may be a highly efficient alternative solution for pond production. In comparison to the traditional outdoor technologies, indoor methods can ensure either very low fish losses (e.g. Wolnicki and Myszkowski 1998a, Wolnicki et al. 2002, Wolnicki et al. unpublished data) or considerable improvement in growth and development rates (Myszkowski et al. 2000, Wolnicki et al. 2000a). The problem is that the rearing under controlled conditions should be based on the use of easily obtainable dry commercial feeds that satisfy all the nutritional requirements of fish.

However, in contrast to early juveniles of typical predatory species such as pike *Esox lucius* L., wels *Silurus glanis* L. or zander *Sander lucioperca* L. which efficiently utilize most commercial starters (Wolnicki and Górny 1997, Zakęś 1997, Wolnicki et al. 1998, Wolnicki and Myszkowski 1998b), the same diets prove to be much less effective for young stages of the majority of cyprinids (e.g. Wolnicki 1996, 1997, Wolnicki and Myszkowski 1998a, 1999, Wolnicki et al. 2002).

Among the most commonly observed effects of commercial starters on cyprinid fish are low growth rate and/or low survival rate (Sierra et al. 1995, Quiros and Alvariño 1997, 1998, Wolnicki and Myszkowski 1999, Quiros et al. 2002), poor food conversion (Wolnicki et al. 2002), high variability of individual size (Backiel 1986, Wolnicki et al. 2002), lowered biological quality (Wolnicki and Myszkowski 1999) and body deformities (Rennert et al. 2000, Wolnicki et al. 2000b, Wolnicki et al. unpublished data). At least some of these phenomena seem to result from the generally high fat content in commercial starters (Wolnicki et al. 2002).

No data are available on the use of dry diets for intensive rearing of early stages of crucian carp *Carassius carassius* L., which has become a desirable species for restocking in Poland. The aim of the present study was to compare some quantitative and qualitative features of crucian carp juveniles fed different starters under controlled conditions.

## Material and methods

### Fish and their preparation for the experiment

The crucian carp juveniles used in the present experiment were the progeny of the artificial breeding of six females and two males caught in a small nameless pool in the vicinity of Gdańsk in northern Poland. Before the beginning of the experiment, the progeny were reared from the first feeding over a 5.5-month preparatory period at a water temperature of 22°C in 40 dm$^3$ glass aquaria. The fish were fed with live *Artemia* nauplii (days 1-25), a combination of *Artemia* nauplii and a dry diet (days 26-100) or a dry diet alone (days 101-165).

### Diets and feeding

Four dry diets of similar particle size were used in the experiment (Table 1). Two of them were commercial starters for common carp (Carp Starter, Aller Aqua, Denmark; CS diet in this paper) or eel (EEL diet, Trouw Spain) with a crude fat content of 10 or 15.9%, respectively. The two remaining diets were the Polish experimental carp starters with crude fat contents of 7.4 (ASTA I) and 9.8% (ASTA II). All the starters were fed in excess to the fish manually every three hours between 08.00 and 20.00. Daily feeding rates, adjusted monthly, were similar in all the experiment groups. They gradually decreased from around 5.5 to 2.5% of the fish total biomass on the first and last day of the trial, respectively.

**Table 1**
General characteristics of dry diets used in the experiment

| | Diets | | | |
|---|---|---|---|---|
| Dietary composition | CS | EEL | ASTA I | ASTA II |
| Crude protein (%) | 45.0 | 51.2 | 50.7 | 52.4 |
| Crude fat (%) | 10.0 | 15.9 | 7.4 | 9.8 |
| Gross energy (MJ kg$^{-1}$) | 18.5 | 22.1 | 18.5 | 18.9 |
| Particle size range (mm) | 0.5-1.3 | 0.5-1.7 | 0.7-1.5 | 0.7-1.5 |

### Experimental procedures

After the completion of the preparatory period, the crucian carp were stocked in eight glass flow-through aquaria with a water volume of 20 dm$^3$. The aquaria were supplied with water originating from a recirculation system with a biofilter, and the water exchange ratio was equal to once per hour. The water was aerated and heated to 25°C (range ± 0.5°C). Artificial illumination was provided between 08.00 and 21.00. Every evening the aquaria were cleaned of feces and uneaten feed. The dissolved oxygen saturation in the aquaria was maintained at no less than 50%. The total ammonia and nitrite concentration in the aquaria were kept below 0.1 and 0.02 mg dm$^{-3}$, respectively.

A random sample of 100 fish was anesthetized by immersion in a 2-phenoxyethanol solution at a concentration of 0.45 g dm$^{-3}$, and their total length (TL) and wet body weight (BW) were determined individually to the nearest 0.1 mm and 0.01 g, respectively. On the basis of this sample, the fish size distribution in the population was estimated. Only fish with a body weight between 0.25 and 0.60 g inclusively were selected for the experiment.

It was assumed that the fish size distribution in each aquarium reflected its distribution in the population. Therefore, for stocking purposes the fish were divided into five body weight (g) categories: (0.25-0.29); (0.30-0.34); (0.35-0.39); (0.40-0.44); (0.45-0.60). While stocking the experimental aquaria, each fish was measured (to the nearest 0.1 mm) and weighed (to the nearest 0.01 g), then it was placed in the appropriate aquarium. The number of fish belonging to each size class already placed in each aquarium was continuously monitored with a specially designed computer program. Finally, each aquarium contained 100 fish with an initial average total length of 31 mm and average body weight of approximately 0.36 g (Table 2).

Every 30 days, all the fish from one aquarium (always the same) from a pair constituting an experimental group were fished out, anesthetized in 2-phenoxyethanol, individually weighed, then placed on a flatbed scanner and a group image was taken. The total length of each fish was then determined using a computer and an image analysis program.

The experiment lasted 120 days. On the final day, all the fish from each aquarium were anesthetized and then counted. The total lengths and wet body weights were determined individually, and the number of fish with body deformities was recorded.

## Calculations and statistics

The condition coefficient (K) was calculated with the following formula:

$$K = 10^5 \quad [BW\ (g)]/[TL\ (mm)]^3 \qquad (1)$$

The daily increment in fish total length was calculated according to the following formula:

$$ITL\ (mm\ d^{-1}) = (average\ final\ TL - average\ initial\ TL)/120 \qquad (2)$$

Student's t-test was performed to examine the differences in the final mean BW, TL and K between the two aquaria in each experimental group. Since no statistically significant ($P > 0.05$) differences were found, it was assumed that fish from a pair of aquaria constituted a homogenous population in all cases.

The differences in the final TL, BW, and K between experimental groups were examined using Duncan's multiple range test. The differences were considered statistically significant at the probability level $P \leq 0.05$.

Final survival percentages were normalized using angular transformation (Sokal and Rolf 1969), and the differences were considered significant at $P \leq 0.05$.

**Table 2**
Initial and final characteristics of crucian carp juveniles reared at a temperature of 25°C for 120 days

| | CS | EEL | ASTA I | ASTA II |
|---|---|---|---|---|
| Final survival (%) | $99.5^a$ | $96.5^b$ | $97.5^{ab}$ | $98.5^{ab}$ |
| Initial total length (mm ± SD) | $31.3 \pm 2.03^a$ | $31.1 \pm 2.07^a$ | $31.4 \pm 1.93^a$ | $31.3 \pm 2.05^a$ |
| Final total length (mm ± SD) | $61.0 \pm 5.44^c$ | $61.6 \pm 4.3^c$ | $64.0 \pm 5.18^b$ | $67.7 \pm 5.76^a$ |
| Increment in TL (mm $d^{-1}$) | 0.25 | 0.25 | 0.27 | 0.30 |
| Initial body weight (g ± SD) | $0.36 \pm 0.07^a$ | $0.36 \pm 0.08^a$ | $0.36 \pm 0.07^a$ | $0.36 \pm 0.08^a$ |
| Final body weight (g ± SD) | $3.88 \pm 1.12^b$ | $4.15 \pm 0.92^a$ | $3.75 \pm 1.01^b$ | $4.33 \pm 1.24^a$ |
| Initial condition coefficient (K ± SD) | $1.16 \pm 0.08^b$ | $1.18 \pm 0.08^a$ | $1.15 \pm 0.08^b$ | $1.17 \pm 0.08^{ab}$ |
| Final condition coefficient (K ± SD) | $1.66 \pm 0.08^b$ | $1.75 \pm 0.09^a$ | $1.39 \pm 0.09^c$ | $1.36 \pm 0.08^d$ |
| Deformed individuals (%) | 37.2 | 62.7 | 0.0 | 0.0 |

Data in the same rows with the same superscripts do not differ significantly at P = 0.05

## Results

### Survival

The final survival rates were very high in all the experimental groups (Table 2). The lowest value of 96.5% was found for the fish fed the EEL diet and was significantly (P ≤ 0.05) lower than that recorded for group CS.

### Growth

Significantly the largest final average total length was found for the fish fed the ASTA II diet (67.7 mm, Table 2), whereas the fish fed the EEL and CS diets showed the slowest growth in length at 61.6 and 61.0 mm, respectively. The daily increments in fish total length ranged from 0.25 (CS and EEL) to 0.30 mm (ASTA II).

No significant difference was found between the final fish body weight in the ASTA II (4.33 g BW) and EEL (4.15 g BW) groups; however, both these values were significantly higher than those recorded for the CS and ASTA I groups (3.88 and 3.75 g, respectively – Table 2).

### Condition coefficient

The final condition coefficient values differed significantly. The highest average value was recorded for the EEL diet-fed fish (K = 1.66) whereas the lowest one was found for the ASTA II group (K = 1.36, Table 2).

### Body deformities

Over the course of the experiment an increasing number of deformed fish was observed in groups fed commercial starters. The deformities were mostly scoliosis and bent fins. On the final day, the percentage of deformed individuals reached 62.7 and 37.2% in the EEL and CS groups, respectively (Table 2). No deformities were found in the fish fed either of the ASTA diets.

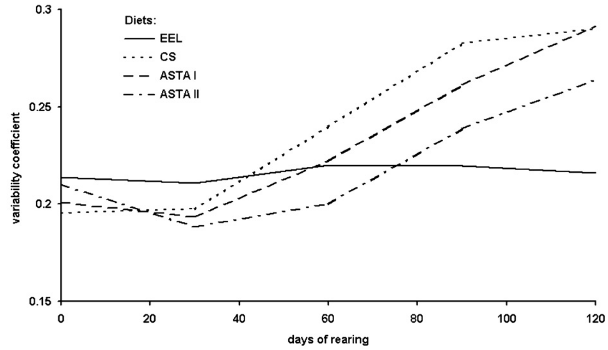


Figure 1. Changes of the total length variability in juvenile crucian carp fed different diets (variability index = standard deviation-/mean).

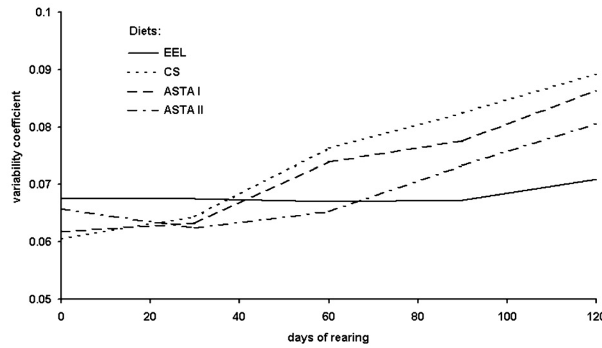


Figure 2. Changes of the body weight variability in juvenile crucian carp fed different diets (variability index – see Figure 1).

### Size variability

From day 60 onwards, fish size variability increased in all groups except for the one fed the EEL diet (Figs. 1 and 2). In this group the variability coefficient values for TL and BW were nearly constant until the end of the experiment.

## Discussion

Feeding juvenile cyprinids with commercial starters formulated for salmonid fish usually produces poor results (Wolnicki and Myszkowski 1999, Quiros et al. 2002). Thus, it is necessary to try new approaches to find appropriate diets for cyprinid species. It is known from previous studies with juvenile tench *Tinca tinca* (L.) (Quiros et al. 2002) that the eel feed used in the present experiment is considerably more efficient than some commercial trout starters. The second commercial feed used in this trial, Carp Starter, is one of only a few diets designed specifically for cyprinid fish. However, our results proved both these starters to be of no practical use for the intensive rearing of crucian carp due to the high percentages of abnormal individuals (Table 2). On the other hand, it should be stressed that all of the fish fed ASTA diets featured regular body shape.

In contrast to body deformities, the crucian carp growth rates obtained in this study were similar for all starters (0.25 to 0.30 mm $d^{-1}$ ITL, Table 2). These results are comparable to those obtained with many other juvenile cyprinids fed exclusively dry diets. For instance, the nase *Chondrostoma nasus* (L.) fed Carp Starter may attain 0.25 to 0.29 or even 0.32 mm $d^{-1}$ ITL when fed ASTA II diet (Wolnicki and Myszkowski 1999, Wolnicki and Myszkowski unpublished data). Juvenile vimba *Vimba vimba* (L.) obtained 0.30 mm $d^{-1}$ ITL on Carp Starter (Wolnicki et al. unpublished data). On the other hand, with juvenile tench fed Carp Starter at a temperature of 24°C, Wolnicki and Myszkowski (1998a) observed a growth rate of only 0.13 mm $d^{-1}$ ITL. Even at 28°C, which is considered the optimal growth temperature for tench, their growth rate on Carp Starter exclusively or in combination with natural food was not higher than 0.21 mm $d^{-1}$ ITL (Wolnicki et al. 2002).

The final survival rates of juvenile crucian carp were extremely high (96.5 to 99.5%, Table 2) which is not very common in the rearing of juvenile cyprinids on dry diets exclusively (e.g. Wolnicki and Myszkowski 1998a, Rennert et al. 2000, Quiros et al. 2002). The very high fish survival rates and satisfactory growth on all diets in the present experiment would indicate that 25°C is very close to the temperature optimum for rearing crucian carp juveniles. It is known from many studies that this temperature is favorable for the juvenile stages of the majority of cyprinid species including barbel *Barbus barbus* (L.), *Ch. nasus*, *T. tinca* or *V. vimba* (e.g. Wolnicki 1996, 1997, Wolnicki and Myszkowski 1999, Wolnicki et al. 2000a).

Many results of feeding trials with fish juveniles indicate that the condition coefficient value may be positively influenced by the fat content in a dry diet (Brecka et al. 1995, Wolnicki et al. 2000b, 2002, De Pedro et al. 2001, Zakes et al. 2001). The results obtained in this study of crucian carp (Table 2) are generally in agreement with the aforementioned statement. However, the condition coefficient value in the CS-fed fish proved to be significantly higher than in the fish fed the ASTA II diet with only a slightly lower fat content. Since the fish fed the former diet showed slower growth in comparison with the latter, it can be concluded that this was a consequence of the considerable differences in the protein content in these diets (Table 1).

Commercial starters with a high crude fat content that are used at high water temperatures for intensive feeding often result in the deposition of large quantities of fat in fish tissues. This may be the origin of pathological changes in their organs (Gomułka et al. 2000) or body deformations (Hasan et al. 1997, Rennert et al. 2000). In the present experiment, body deformities occurred only in the two groups with the two highest final K coefficients (Table 2); however, this phenomenon cannot be attributed only to the high fat content in these diets. Deformities also occurred in Carp Starter-fed juvenile barbel, although these fish showed regular body shape when fed commercial trout feed with an even higher fat content (Wolnicki et al. 2000a). It seems possible, then, that the excessive deposition of fat in fish tissues might also be caused by a protein/fat ratio in the diet that is too low. Moreover, the ability to utilize different dry diets in fish seems to be species specific.

Many authors suggest that in some species the high variability of individual size could result from strong food competition (e.g. Steffens 1979, Backiel 1986, Szlamińska 1987). In the present study, over the course of the experiment, size variability increased in all fish groups except the EEL group (Figs. 1 and 2). Assuming that high size variability is a result of competition for food, this fact could be explained by the highest gross energy content in the EEL diet (22.1 MJ $kg^{-1}$, Table 1). It seems plausible that crucian carp juveniles receiving more energy than others were less hungry while feeding so they competed for food less intensively.

As evidenced by our results, exclusively dry feeds may be successfully used for juvenile crucian carp rearing in a controlled environment. However, widely available commercial starters, even those formulated for cyprinid species such as Carp Starter, may be of extremely limited usefulness when used intensively.

## References


Backiel T. 1986 – Masking effect of variability of growth on its estimation in juvenile tench, *Tinca tinca* (L.), reared at different temperatures – Pol. Arch. Hydrobiol. 33: 69-95.

Brecka B.J., Hooe M.L., Wahl D.H. 1995 – Comparison of growth, survival, and body composition of muskellunge and tiger muskellunge fed four commercial diets – Prog. Fish-Cult. 57: 37-43.

De Pedro N., Guijarro A.I., Delago M.J., Lopez-Patińo M.A., Pinillos M.L., Alonso-Bedate M. 2001 – Influence of dietary composition on growth and energy reserves in tench (*Tinca tinca*) – J. Appl. Ichthyol. 17: 25-29.

Gomułka P., Zakęś Z., Szkudlarek M. 2000 – Liver degeneration in perch *Perca fluviatilis* (L.) fed dry diet: 81-81 – In: XVIII Zjazd Hydrobiologów Polskich (Eds) B. Czeczuga, J.I. Rybak, Polskie Towarzystwo Hydrobiologiczne, Białystok, 04-08.09.2000 (in Polish).

Hasan M.R., Macintosh D.J., Jauncey K. 1997 – Evaluation of some plant ingredients as dietary protein sources for common carp (*Cyprinus carpio* L.) fry – Aquaculture 151: 55-70.

Myszkowski L., Wolnicki J., Kamiński R. 2000 – Accelerated maturation of barbel *Barbus barbus* (L.) broodstock under controlled conditions: 141-148 – In: II Krajowa Konferencja Hodowców i Producentów Karpiowatych Ryb Reofilnych (Eds) H. Jakucewicz, R. Wojda, Brwinów, 02-03.02.2000 (in Polish).

Quiros M., Alvarińo J.M.R. 1997 – Growth of juvenile tench *Tinca tinca* (L.) under controlled and semi-intensive conditions of culture – Proc: 2nd International Workshop on Biology and Culture of the Tench (*Tinca tinca* L.), Badajoz, 02-06.09.1997.

Quiros M., Alvarińo J.M.R. 1998 – Growth of tench (*Tinca tinca* (L.)) fed with and without the addition of the cladoceran *Daphnia* – Pol. Arch. Hydrobiol. 45: 447-451.

Quiros M., Nicodemus N., Alonso M., Bartolomé M., Écija J.L., Alvariño J.M.R. 2002 – Survival and growth of juvenile tench (*Tinca tinca*) fed different diets under water recycled systems – J. Appl. Ichthyol. (in press).

Rennert B., Kohlman K., Hack H. 2000 – A performance test with five different strains of tench (*Tinca tinca*) under controlled warm water conditions – Proc: 3rd International Workshop on Biology and Culture of the Tench (*Tinca tinca* L.), Machern, 11-15.09.2000.

Sierra A., Sáez-Royuela M., Carral J.M., Celada J.D., Gaudioso V.R., Muňoz C., Pérez J.R. 1995 – Response of tench (*Tinca tinca* (L.)) fed five different diets under intensive conditions – Pol. Arch. Hydrobiol. 42: 207-210.

Sokal R.R., Rohlf J.R. 1969 – Biometry. The principles and practice of statistics in biological research – San Francisco, H.F. Freeman and Co.

Steffens W. 1979 – Die Stückmassenverteilung in Beständen einsommeriger Karpfen aus Warmwasseranlagen und Teichen – Z. Binnenfisch. DDR 26: 170-175.

Szlamińska M. 1987 – Survival, growth and size structure of carp (*Cyprinus carpio* L.) larvae populations fed dry feed Ewos larvstart C-10 or zooplankton or else starved – Pol. Arch. Hydrobiol. 34: 331-346

Wolnicki J. 1996 – Intensive rearing of larval and juvenile vimba, *Vimba vimba* (L.), fed natural and formulated diets – Pol. Arch. Hydrobiol. 43: 447-454

Wolnicki J. 1997 – Intensive rearing of larval and juvenile barbel *Barbus barbus* (L.) on commercial dry diets – Rocz. Nauk. Pol. Zw. Wędkar. 10: 7-14 (in Polish).

Wolnicki J., Górny W. 1997 – Effects of commercial dry diets and water temperature on growth and survival of northern pike, *Esox lucius* L., larvae – Pol. Arch. Hydrobiol. 44: 351-357.

Wolnicki J., Kamiński R., Myszkowski L. 2002 – Effect of supplementation of a dry feed with natural food on juvenile tench *Tinca tinca* (L.) growth, condition, size distribution and food conversion – J. Appl. Ichthyol. (in press).

Wolnicki J., Myszkowski L. 1998a – Evaluation of four commercial dry diets for intensive production of *Tinca tinca* (L.) juveniles under controlled conditions – Pol. Arch. Hydrobiol 45: 429-434.

Wolnicki J., Myszkowski L. 1998b – Survival, growth and food conversion in European wels, *Silurus glanis* L., larvae fed dry commercial diets at 28°C – Pol. Arch. Hydrobiol. 45: 531-538.

Wolnicki J., Myszkowski L. 1999 – Comparison of survival, growth and stress resistance in juvenile nase *Chondrostoma nasus* (L.) fed commercial starters – European Aquaculture Society Special Publication 27: 256-257.

Wolnicki J., Myszkowski L., Kamiński R. 2000a – Accelerated maturation of chub *Leuciscus cephalus* (L.) broodstock under controlled conditions – In: II Krajowa Konferencja Hodowców i Producentów Karpiowatych Ryb Reofilnych

(Eds) H. Jakucewicz, R. Wojda, Brwinów 02-03.02.2000 (in Polish).

Wolnicki J., Przybył A., Starzonek I. 1998 – Evaluation of five dry diets for initial feeding of European wels *Silurus glanis* L. under controlled conditions – Arch. Pol. Fish. 6: 123-133.

Wolnicki J., Stanny L.A., Kamiński R., Myszkowski L. 2000b – New starters for cyprinid fish larvae: An opportunity for mass rearing in Poland? Tests on barbel *Barbus barbus* (L.) – Komun. Ryb. 1: 10-12 (in Polish).

Zakęś Z. 1997 – The effect of stock density on the survival, cannibalism and growth of summer fry of European pikeperch (*Stizostedion lucioperca* L.) fed with artificial food in controlled conditions – Arch. Pol. Fish. 5: 305-311.

Zakes Z., Szkudlarek M., Wozniak M., Karpinski A., Demska-Zakes K. 2001 – Effect of dietary protein: fat ratios on metabolism, body composition and growth of juvenile pikeperch *Stizostedion lucioperca* (L.) – Czech J. Anim. Sci. 46: 27-33.