

Influence of free choice of feed on the productive qualities of two-year-old carp (*Cyprinus carpio* L.) in ponds

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Abstract. The results of research on the effect of feed with different feeding values and organoleptic properties on the productivity of two-year-old carp are presented. Within the same pond, the joint use of demand feeders (feeds with different tastes) makes it possible for fish to choose one of them in response to well-developed chemoreception. Diets of different calories affect the quality of the resulting fish production at different feed consumption. The combination of two feed types within one pond provides fish food savings per gain, despite the higher total consumption. Two-year-old fish give preference to more high-energy fish food. At the same time, fish consume 1/3–1/4 of low-energy food, regardless of the feeding time. The mass of fish consuming only low-energy fish food is 1.7 and 2.6 times less than that of fish consuming only high-energy fish food and fish simultaneously consuming these two foods, respectively. Combined feeding contributes to an increase in the relative muscle mass, primarily in comparison with fish fed only a high-energy diet. Fish-farming biological characteristics indicate higher fish yielding qualities in the case of simultaneous use of two types of feed (K-111 and Karp-38/12). Taste priorities must be considered in aquaculture fish farming.

1 Introduction

The method of fish auto- or demand-feeding, first proposed in the Soviet Union by Lavrovsky and based on the use of pendulum demand feeders, allows the fish to self-supply with food according to their needs (V.V. Lavrovsky, 1982). Abroad, it is known as "demand feeding" (A. Alanara, 1992). It is considered that food intake from pendulum demand feeders is optimal, since in this case, the fish regulate this process themselves, considering the environmental conditions by their sensory organs and correlating them with their internal biorhythms, including spontaneous ones [1, 2, 3]. The effectiveness of this feeding is confirmed by studies on various fish species [4, 5, 6, 7]. However, the free food intake from demand feeders by fish depends on some factors. These include the ability of different fish species to use such a system (P.J. Landless, 1976), temperature (A. Alanara, 1994),

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photoperiod (T. Boujard, J.F. Leatherland, 1992), portions of food (E. Brannas, A. Alanara, 1994), growth rate [3], planting density (A. Alanara, E. Brannas, 1996), social dominance (A. Gelineau, G. Corraze, T. Boujard, 1998), and the diet energy value [8].

Fish have well-developed chemoreception due to olfactory and gustatory analyzers [9, 10, 11, 12, 13, 14]. Studies aimed to identify the preference of feeds with one or another smell and taste are numerous, but, as a rule, they are not related to the determination of the fish yielding qualities (A.O. Kasumyan, K.B. Doving, 2003; T.J. Hara, 1994; Y. Goh, T. Tamura, 1980; W.E.S. Carr, M. Kenneth, K.M. Blumenthal, J.C. Netherton, 1977).

Artificial fish food with uniform organoleptic properties does not provide fish with a choice to fully satisfy their trophic needs. When using demand feeders with different feeds in the same pond, fish have the opportunity to be motivated (appetite) to one of them due to chemoreception. The alternation of eating different fish foods leads to an overall increase in their consumption and, often, to an increase in productivity. Favoring some fish food in fish can be established by their consumption intensity. This, in turn, characterizes the fish's appetite, which affects growth and their productive qualities.

The purpose of the study is to identify the influence of various feed concentrates, including when they can be selected, on the yielding qualities of two-year-old carp.

2 Materials and Methods

The work was carried out on the basis of the All-Russian Research Institute of Freshwater Fisheries (now a branch of VNIRO), in the Experimental Selection and Breeding Farm "Yakot", Dmitrovsky District, Moscow Region. The study objects were yearlings and two-year-old carps.

The experimental design is presented in Table 1. The studies were carried out from April to October 2019 in 6 ponds with an area of 0.07 ha each, in duplicate. The fish-holding density of yearlings was 7000 individuals/ha. The fish were fed from pendulum demand feeders with a 25 kg bunker capacity with K-111 and Karp-38/12 feed concentrates by a bionic feeding method (V.V. Lavrovsky, 1982). In Variant I, the researchers used K-111 feed concentrate (in both demand feeders), in Variant II – Karp-38/12 (in both demand feeders), in Variant III – K-111 and Karp-38/12 (in different demand feeders). From April (from stocking, April 18, 2019) to the second half of May, the fish in the test ponds consumed natural food. In the first (May 5–6) ten days of May, demand feeders were positioned in the ponds. After 20 days, the fish began to consume food from them. From that time until the end of the first ten days of June, second-summer carps in Variant I received K-111 feed concentrate, and in Variants II and III they received Karp-38/12. Subsequently (before the finishing fishing, October 11, 2019), fish in the ponds of Variant III used two types of K-111 and Karp 38/12 fish foods, filled in different demand feeders, i.e. second-summer fish had a free choice of feed.

K-111 feed concentrate contains 23% crude protein, 3.5% fat, no more than 8% fiber, 10 MJ/kg of digestible energy. The energy-protein ratio is 10.3. Karp 38/12 feed concentrate contains 38% crude protein, 12% fat, no more than 3.5% fiber, 17.1 MJ of digestible energy. The energy-protein ratio is 10.7.

Table 1. Experimental design.

Characteristic	Variant		
	I(K- 111)	II (Carp-38/12)	III (K-111, Carp-38/12)
Average fish weight, g	30	30	30
The fish-holding density, ex. / ha	7000	7000	7000

The pond area, ha	0.07	0.07	0.07
Number of demand feeders, pcs.	2	2	2
Type of feed	K-111	Carp 38/12	K-111, Carp 38/12

Sampling (6–10 fish) was carried out at the beginning and end of rearing. In fish, the mass was determined within an accuracy of 0.1 g, the lengths (large, short, length of head and tail) and high and low heights were measured. The body condition coefficient was estimated according to Fulton. The physical analysis was used to establish the ratio of fish body parts and liver weight. Fat was extracted from the abdominal cavity of second-summer fish, and the fat coefficient was calculated. The data obtained were expressed as a percentage by fish mass.

Samples to determine the chemical composition of fish were taken from the middle sections of the white (glycolytic) and all red (oxidative) muscles, and the prepared liver. The samples were dried in a loss-on-drying oven at 105 °C. Calculations were counted on water and dry matter. The amount of fat was determined in a Soxhlet apparatus and expressed as a percentage of the wet matter. The protein content was determined according to the solids-not-fat (SNF) which contains 86–92% protein. The caloric content of the muscles was based on 38.9 KJ per 1 g of fat and 17.2 KJ per 1 g of protein.

Fish-farming and biological characteristics were calculated according to the average values of each test variant. The average muscle mass without morphofunctional type separation was used as a basis for determining the yield of protein and fat.

The data obtained were processed statistically by standard methods.

3 Results

When using demand feeders, fish foods of different formulations have an ambiguous impact on the processes associated with the growth of two-year-old carp; their effectiveness is not the same. Judging from the results obtained, the carp growth with the low-calorie K-111 fish food concentrate was not as intense as in other experimental ponds. The fish weight when using low-energy fish food was 1.7 and 2.6 times lower than that of fish receiving high-energy food and their compound, respectively. The highest feed/gain costs were noted when using K-111 food concentrate. The two-feed type combination provides fish food savings per gain, despite the higher total consumption (Table 2).

Table 2. Fish-farming and biological characteristics (on average for variants).

Characteristic	Stocking	Fishing		
		K-111	Carp-38/12	K-111, Carp-38/12
Fish weight, g	30	572.0	986.7	1220.0
Fish length, cm,	13.1	31.9	33.7	37.8
Fish weight gain, g	-	542	966.7	1190.0
Feed, kg	-	439	511	536.5
Feed, kg/gain, kg	-	2.41	1.55	1.37
Fish condition factor	1.34	1.76	2.57	2.29
Survivalship, %	-	69.2	69.8	66.0

The use of Karp 38/12 feed concentrate and its combination with K-111 feed concentrate allows increasing the fish fatness by 1.5 and 1.3 times, which indirectly may indicate a better physiological state and commercial qualities of hydrobionts. The two-year-old fish survival rate is relatively low and does not differ significantly in the test ponds. Figure 1 shows the consumed feed ratio in Variant III.

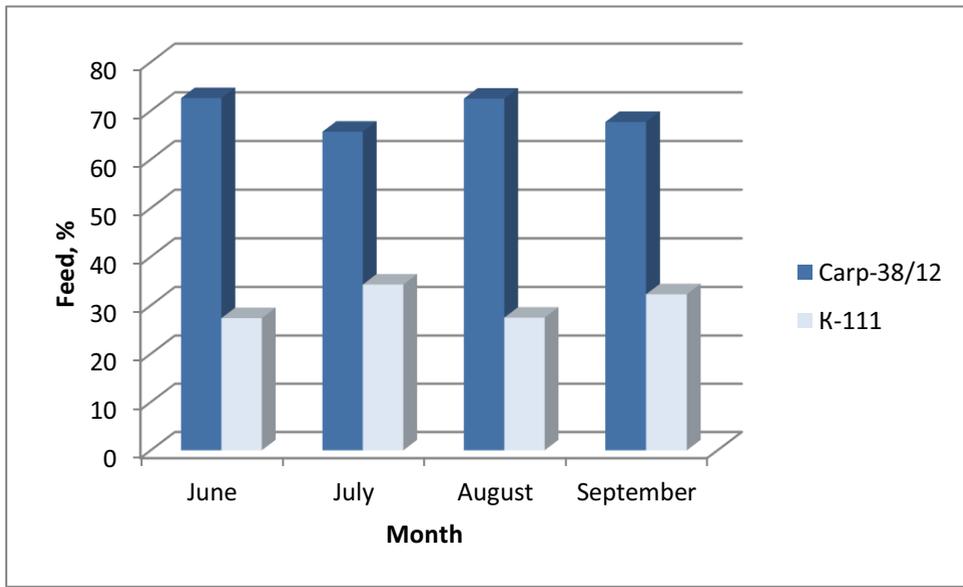


Fig 1. Feed ratio in Variant III, %

Of course, fish prefer fatty food. At the same time, 1/3–1/4 of low-energy food is consumed, regardless of the feeding time. This matters, because it can be assumed that a low-energy fish food with a high-energy fish food will increase nutrition. In the human diet, fatty foods with vegetable seasoning are consumed much more willingly. A similar trophic requirement may be observed in fish with well-developed taste buds. Table 3 shows the body part ratio of the two-year-old carp depending on the fish food type.

Table 3. The body part ratio of two-year-old fish depending on the fish food type (in % of fish weight) n=6-9 fish

Characteristic	Stocking	Fishing		
		K- 111	Carp-38/12	K-111, Carp-38/12
Muscles	23.8±1.09	37.4±1.23*	34.7±2.21*	40.6±0.14*
Head	29.7±2.38	15.9±0.85*	13.8±1.00*	14.1±0.23*
Fins	1.47±0.23	1.94±0.09	1.87±0.24	1.76±0.02
Scales	4.90±0.96	3.67±0.20	3.66±0.01	3.42±0.08
Skin	8.69±1.13	7.47±0.67	7.87±0.24	7.57±0.16
Visceral fat	-	2.18±0.43	2.84±0.73	4.33±0.23

* – the difference compared to the stocking period is significant at P≤0.05.

Such yielding qualities of fish as the body part ratios change regardless of the fish food type and its combination. At the end of cultivation, two-year-old fish have a significant increase in the relative mass of the transversely striated trunk and tail muscles, fins, and intracavitary fat and a decrease in the head and scale proportion. The axial muscles forming the soma basis grow most intensively. Their proportion increases in fish in the following

Variants: I by 1.6, II by 1.5, and III by 1.7 times ($P \leq 0.05$). When ponds were stocked in spring, carp yearlings had a large head (actually 1/3 of the fish mass), and during the feeding period (within 6 months), this characteristic value significantly changed downward ($P \leq 0.05$). Combined feeding leads to an increase in the relative muscle mass, to a greater extent compared with fish fed only a high-energy diet ($P \leq 0.05$). At the same time, the relative head size in fish from different test variants is quite close (13.8–15.9%) (the difference is not significant). The combination of the two types of fish food promotes endocavitary fat accumulation, especially in comparison with fish fed a low-energy diet (in fact, by 2 times) ($P \leq 0.05$). Table 4 shows the chemical composition of the muscles and liver of two-year-old carp in different test variants.

Table 4. Chemical composition of muscles and liver of two-year-old carp (in % of raw material) (n=3)

Characteristic	Stocking	Fishing		
		K- 111	Carp-38/12	K-111, Carp-38/12
White muscles				
Dry matter	15.1±0.60	23.6±1,01*	25,8±1,69*	23,5±0,77*
Fat	0.5±0.15	3.9±0,74*	3,5±0,31*	4,6±0,79*
SNF	14.6±0.51	1.7±1,21*	22,3±1,65*	18,9±0,12*
Red muscles				
Dry matter	-	28,8±4,90	38,1±0,50	34,6±3,69
Fat	-	15,5±3,90	16,3±1,19	19,3±3,83
SNF	-	13,3±1,80	21,8±1,19*	15,3±0,15
Liver				
Dry matter	-	28,8±2,45	43,0±3,09*	39,1±2,24*
Fat	-	8,8±1,16	17,3±1,85*	13,9±2,16*
SNF	-	20,0±2,06	25,7±2,21	25,2±1,77

For white muscles – * the difference compared to the stocking time is significant at $P \leq 0.05$. For red muscles and liver – * the difference compared to Variant I (K-111) is significant at $P \leq 0.05$.

Since the axial musculature of the carp consists of two main types (white and red) of muscles, when determining the chemical composition, it is important to distinguish them as independent structures. Red or superficial lateral muscles in the body of the two-year-old carp are an insignificant part of the somatic muscles, but they play an important role in metabolic processes. In addition to muscle mass, the liver (hepatopancreas) plays an important role in the hydrobiont life, the intensive accumulation of fat and glycogen is its characteristic feature, regardless of the protective function.

In the process of rearing two-year-old fish, the fat and SNF content in-creases and the water level decreases.

When using two fish food types (K-111 and Karp-38/12) within the same pond, a slightly more intense fat accumulation was noted in the white muscles of fish than in fish from other test variants. This happens, to some extent, to the detriment of the SNF content.

A similar situation is observed in the red muscles. Compared to white muscles, red ones have a higher dry matter content in which a significant part is accounted for by the fat component. When a high-energy fish food is used, the SNF accumulates more intensively in the carp red muscles.

Like red muscles, the liver is involved in fat metabolism. Moreover, the accumulation of the fatty component in it is associated with the type of fish food consumed. The liver of fish reared with Karp 38/12 contains the maximum amount of both fat and SNF. In these fish, the

liver fat content is 1.9 ($P \leq 0.05$) and 1.2 times higher than in Variants I and III, respectively. Perhaps, the increased fat deposition in the fish liver in Variant II is not a positive sign, since there is a danger of its fatty degeneration.

The yielding qualities of two-year-old carp depending on the fish food type at the end of the experiment are presented in Table 5.

Table 5. Productive qualities of two-year-old carp

Characteristic	K- 111	Carp-38/12	K-111, Carp-38/12
Fish yielding, pcs./ha	4948	4991	4333
Total ichthyomass, kg/ha	2830,0	4825,6	5286,7
Quantity, kg/ha:			
raw meat (muscle)	1059,6	1708,8	2146,4
dry matter	250,3	440,4	504,8
Fat	41,3	60,0	98,7
SNF	208,8	380,4	406,1
Energy value, MJ	5,2	8,9	10,8

Despite the lower yield of two-year-old fish from ponds with combined feeding, the total ichthyomass in them is significantly (1.9 times) higher especially in comparison with Variant I. Accordingly, the combination of two fish food types in one pond can increase the individual and total meat yield of fish. The amount of raw meat per 1 hectare of the pond area, in this case, is 2 and 1.3 times higher than in Variants I and II, respectively. Since the dry matter in the muscles is determined by the fat and protein (SNF) components, their weight fraction is also higher in fish in ponds with a mixed set of feeds. The chemical composition of muscles, for its part, characterizes the energy value of fish as a food product. The product energy value obtained from 1 ha of the pond water area when feeding with fish food of two types exceeds similar characteristics in other test variants (Table 4).

4 Discussion

Fish foods of different energy values affect the morphophysiological parameters and yielding characteristics of two-year-old carp when fattening. High-energy fish foods promote more efficient utilization of nutrients as a protein-saving effect (I.N. Ostroumova, 1983, 1988). By increasing the fat content in the fish diet, virtually the same amount of protein can be saved (T. Wanatabe, 1977).

The relative amount of muscles is not related to the fish food energy value and their combination has a stimulating effect on both the fish weight and the muscular somatic component. However, this does not affect feed consumption, which is even slightly lower than in other test variants. The fish food quality affects the processes of fat deposition inside the fish body cavity. In trout fed with fishmeal, the mesenteric fat deposition is lower than in fish fed with the vegetable component (M. de Francesco et al., 2004). The addition of 5–7% of vegetable vitamin fodder lipids to the trout feed leads to an increase in intracavitary fat as compared to the RGM-5V fish food (4.35 versus 3.56%) (V.P. Panov, V.V. Lavrovsky, Yu.I. Esavkin, V.V. Smirnov, 1994). The authors' data indicate that combined nutrition in two-year-old carp, along with an increase in muscle mass, causes an increased adipopexis inside the body cavity.

At the same time, it is known that high-energy fish foods promote fat deposition in the fish muscles, both epaxial and hypaxial ones (L.R. Gary, T.C. Yu, 1991, W. Steffens, M. Wirth, B. Rennert, 1995).

The data obtained indicate that in carp (excluding visceral fat), the white muscle contains 41.2 to 61.1% of fat reserves, in the red ones – 13.8 to 19.5%, in the liver – 24.5 to 39.3%. The highest values of this characteristic in the white muscles were noted when the fish consumed the K-111 fish food (61.1%). When using the Karp 38/12 fish food, the depositing role of white muscles is significantly lower (41.1%). When using only high-energy fish food, the red muscles and liver of fish are distinguished by a well-defined ability to accumulate adipose tissue [16]. There is a view that red muscles perform some of the liver functions. This view is based on the fact that pelagic fish have well-developed superficial lateral muscles in comparison with benthic species, in which the liver reaches a large size (R.M. Love, 1976, C. Wittenberger, *Revue Roum. de Biologie*, 1967, O.R. Brackkan, 1956). Similar data were obtained for the relatively inactive ratan (V.P. Panov, 1990). It should be noted that excessive adipopexis by hepatopancreas cannot be considered a positive factor for the normal physiological state of the carp organism. In salmon, 38.4% of fat reserves are deposited in the dorsal white muscles, 28.1% – in the red muscles, and 27.2% in the muscles of the abdominal region (M. Aursand et al, 1994). Depending on the feed intake, the SNF content in the fish white muscles and liver changes to a lesser extent than a fat one. The greatest differences in the characteristic value are observed in red muscles which are determined by the amount of dry matter and fat in them. In general, the muscles and liver of carp consuming Karp 38/12 fish food have a higher protein content.

Fish-farming biological characteristics based on morphological tests indicate higher fish yielding qualities when combining the use of two types of feed. This results in a higher yield per unit area of meat and, accordingly, fat and protein of two-year-old carp. The energy value of the products obtained when used within one pond with different compositions of fish food is higher than within other test ponds. Despite the relatively low fish yield due to non-technological reasons, the integrated use of fish foods can increase the productivity of ponds. This is possible when using demand feeders, allowing for distributions from various feeding stuff types.

5 Conclusions

At the same time, it has been found that two-year-old carp prefers Karp 38/12 pellets to a greater extent but 1/3-1/4 of the total diet falls on the low-energy K-111 fish food. This implies a differentiated food preference in fish during certain feeding periods, which requires additional research that will determine the biotic and abiotic conditions under which fish prefer a certain fish food. These studies once again confirm the need to consider taste priorities in aquaculture fish farming.

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