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Research Progress on Nutritional Requirements of Carp

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Abstract Carp is a temperate freshwater fish native to Asia, distributed in all regions of the world except Australia and South America. With the improvement of comprehensive and healthy breeding technology of carp, the unit yield has been greatly increased mainly due to the extensive use of compound feed. In this study, the nutritional requirements of carp were summarized from the aspects of protein, amino acids, fat, carbohydrate, calcium and phosphorus, vitamins and taurine. This study provides a certain theoretical reference for scientific formula of carp feed.

Key words Carp, Nutritional requirements, Foreground

1 Introduction

Carp belongs to *Cyprinus*, Cyprinidae, Cypriniformes, and it is one of the most widely distributed economic fishes in China. Among the existing freshwater fish in China, fishes belong to Cyprinidae account for more than 50%, many of which are unique species in China. In the artificial breeding cost of carp, the feed cost accounts for more than half of the operating cost, so the scientific and economic design of feed formula is the key to improving the economic efficiency of artificial breeding of carp and reducing the cost. Protein, sugar, fat, and other nutrients have a great impact on the growth and development of carp. Insufficient nutrients or the imbalance between various nutrients in the feed of carp will lead to their nutrition waste, slow growth, or being diseased, thereby reducing the economic benefits of artificial breeding of carp.

2 Nutritional requirements of carp

2.1 Effects of protein and amino acids on the growth of carp

2.1.1 Effects of protein on the growth of carp. Most land animals require more than 20% total protein, and even carnivorous felines rarely require more than 38% total protein. The energy required by fish comes mainly from protein and fat, rather than carbohydrates, so fish require higher protein levels. Many researchers have studied the appropriate protein requirements for different fish feeds. For instance, Ogino *et al.* measured that the protein requirement of carp was 30% -32%, and the recommended protein requirement for carp of the same size was as follows: 43% -47% for fry, 37% -42% for little fish one finger in length and juvenile fish, and 28% -32% for adult and female fish. Other studies have shown that crude protein content ranging from 30% to 38% can meet the needs of carp[1].

In the study of protein in juvenile rock carp[2], by using single factor gradient test design, six purified diets containing 25.1%, 30.3%, 34.8%, 40.4%, 44.8% and 49.7% of crude protein were prepared with casein and gelatin as protein sources to feed (7.93 ±0.16) g juvenile rock carp 123 d, so as to investigate the protein requirement of juvenile rock carp. The results showed as follows: (i) the specific weight gain rate, growth rate and protein deposition rate of juvenile rock carp in the experimental group with dietary protein level of 40.4% were significantly higher than those of the other experimental groups ($P < 0.05$), while the feed coefficient of the group with dietary protein level of 40.4% was significantly lower than that of the other experimental groups. (ii) Dietary protein level significantly affected the RNA/DNA ratio of juvenile rock carp. With the increase of protein level, the RNA/DNA ratio increased first and then decreased, reaching the maximum in 40.4% group. (iii) The crude protein of whole fish in the experimental group with dietary protein level of 40.4% was significantly higher than that in other groups ($P < 0.05$), while the content of crude lipid in the group was lower than that in other groups ($P < 0.05$), and different protein levels had no significant effects on water content and ash content of whole fish ($P < 0.05$). (iv) The regression analysis of dietary protein levels based on weight gain rate, specific growth rate, feed coefficient, muscle RNA/DNA, trypsin activity and glutamate dehydrogenase activity showed that the optimal protein requirement of juvenile rock carp was 40.53% -41.05%. It can be seen that protein content is very important for carp growth.

2.1.2 Effects of amino acids on the growth of carp. Amino acids are the basic constituent unit of protein, and play an important role in fish. By chemical integration method, Mitchell *et al.* proved that the nutritional value of dietary protein depends on its amino acid composition. The more consistent the amino acids that make up protein with the amino acids used by animals for growth and maintenance, the higher the value of protein. Amino acids are the basic unit of protein, the main embodiment of protein nutrition, the main source of energy required by fish, and the main component of hormones, enzymes, antibodies, *etc.* Earlier, researchers replaced dietary protein with crystalline L-amino acid, and found that the same 10 amino acids were needed for normal

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growth in salmon, red salmon, rainbow trout, spotted forktail and eel. By neutralizing amino acid diets with NaOH, Hiroshi Aoe *et al.* found that carp also need the same 10 amino acids. These 10 amino acids are arginine, histidine, lysine, isoleucine, leucine, methionine, phenylalanine, tryptophan, threonine and valine, and they are the essential amino acids required by carp. Besides containing these 10 essential amino acids, fish diet should meet their balance.

Most protein sources, especially plant protein sources, often lack lysine, methionine, arginine and so on, resulting in imbalance of dietary amino acid composition. In order to improve the nutritional value of plant protein feeds such as soybean meal, people often add crystal amino acids to fish feeds to balance the dietary amino acid composition. It was found that salmon and trout can effectively use crystal amino acids, but carp can not use crystal amino acids well. Carp has no stomach, and amino acids are mainly absorbed in the foregut and midgut, so it has not enough buffer capacity for crystal amino acids. Crystal amino acids are absorbed too fast, and cannot be absorbed synchronously with the binding amino acids in the protein state in the feed, so that the amino acids absorbed by the tissue are unbalanced, and the protein synthesis in the body is reduced. In addition, the added amino acids are easily filtered by water, resulting in low utilization. At present, embedding amino acid technology can be used to improve the utilization rate of crystal amino acids by slowing down the absorption rate of crystal amino acids, adjusting amino acids to be neutral to change gastrointestinal pH and enhance palatability, and increasing the feeding frequency to shorten the feeding interval and making the blood amino acids complementary.

It was found that carp can effectively use plant protein sources, so people began to use plant protein sources instead of fish meal. Although it is feasible to substitute fish meal with plant protein sources, the substitution level in carp diet is low, mainly because the amino acid composition of plant protein sources is more unbalanced.

2.1.3 Factors affecting the optimal requirement of protein. The protein in the above data is from high-quality protein sources, such as casein, egg protein and fish meal. Jia Zhicheng *et al.* used full-value feed protein sources (including imported fish meal, cottonseed cake, rapeseed cake, and bean cake) to study the optimal supplemental amount of fish protein, and it was found that the optimal supplemental amount was 43%, and the growth rate of fish body varied greatly when the diet had the same protein content and different protein sources. The difference of the results was related to the individual size, water quality, temperature and other conditions, and the most important reason was that the composition and proportion of amino acids forming dietary protein sources were different.

2.2 Effects of fat on the growth of carp Experiments of fat research: 1.5% fish oil, soybean oil, rapeseed oil, flaxseed oil and lard as a single fat source were added to a practical feed formula to prepare five experimental diets (crude protein content was 35%, and total energy was 15 MJ/kg). An 8-week feeding experiment was conducted to study the effects of different dietary fat sources on the growth performance, hepatopancreas lipid metabolism-related enzymes and antioxidant enzymes activities of carp[1]. A total of 750 carps with an average initial weight of (5.83 ±0.01) g were randomly divided into 5 groups, with 3 replicates per group and 50 fish per replicate. The results showed that the specific growth rate (SGR), protein efficiency efficiency (PER) and feed conversion ratio (FCR) were the best in the fish oil group and the worst in the lard group, and there were significant differences between the two groups ($P < 0.05$). There were no significant differences in SGR, PER and FCR among the soybean oil group, rapeseed oil group and flaxseed oil group ($P > 0.05$). Different fat sources had significant effects on crude protein and crude fat content of whole fish ($P < 0.05$), but had no significant effects on the dry matter and ash content of whole fish ($P > 0.05$). The content of crude protein in whole fish in the fish oil group was the highest, and the content of crude fat was the lowest. Hepatopancreas lipoprotein lipase (LPL) activity was the highest in the fish oil group, followed by the soybean oil group, rapeseed oil group and linseed oil group, and it was the lowest in the lard group. Hepatopancreas malate dehydrogenase (MDH) activity is shown as follows: flaxseed oil group > soybean oil group > fish oil group > rapeseed oil group > lard group. The hepatopancreas superoxide dismutase (SOD) activity in lard group was significantly lower than that in other groups ($P < 0.05$), but there was no significant difference among the other groups ($P > 0.05$). Different fat sources had significant effects on hepatopancreas total antioxidant capacity (T-AOC) ($P < 0.05$), and it was the highest in the fish oil group and the lowest in the lard group[3]. It can be seen that fish oil is a more suitable fat source for carp, while lard is not suitable as a single fat source for carp, because it will damage the health of hepatopancreas and further affect the growth of carp[4-5].

2.3 Effects of sugar on the growth of carp Taking black oligosaccharide as an example, 108 normal healthy carp with an initial body weight of 180 – 190 g were divided into 3 groups, with 36 carps per group and 3 replicates per group. There were three treatments in the experiment, namely control group (basic diet), basic diet $+300 \times 10^{-6}$ oligosaccharide, and basic diet $+600 \times 10^{-6}$ oligosaccharide. After 60 d of experiment, 12 carp were selected from each treatment for transport test, with the transport distance of 500 km and the transport time of nearly 14 h. The results showed that the addition of oligosaccharide in the basic diet significantly improved the growth rate of crap and the utilization rate of feed, and had no effect on the long-distance transportation ability of carp[6-7].

2.4 Effects of other substances on carp growth

2.4.1 Requirement and proportion of calcium and phosphorus for carp growth. Taking the requirement of calcium and phosphorus by Heyuan carp as an example, the appropriate requirement and proportion of calcium and phosphorus for the growth of Heyuan carp were discussed. The results showed that the best ratio of calcium to phosphorus was 1 : 2 regardless of the same requirement of calcium and phosphorus. When the ratio of calcium to phosphorus was 1 : 2, calcium content was 839 – 1 189 mg%, and phosphorus content was 1 678 – 2 378 mg%. The total content of calcium and phosphorus was 2 517 – 3 600 mg%, and Heyuan carp grew best. As the ratio of calcium to phosphorus was less than 2, the high content of calcium and phosphorus would reduce the harm caused by the imbalance of calcium and phosphorus to the growth of Heyuan carp. When the total content of calcium and phosphorus was too much or too little, and the ratio of calcium to phosphorus was not equal to 1 : 2, it would inhibit the growth of Heyuan carp and reduce the conversion rate of feed[8–10].

2.4.2 Demand and proportion of taurine for carp growth. In addition, taurine has a certain effect on the growth and edible nutritional value of carp. After being raised with the feed containing high and low concentrations of taurine (1% and 5%) for 120 d, carp was evaluated by weight, body length, general nutrients in muscle and taurine content. Compared with the control group, the fat content in the muscle of carp significantly decreased, and the taurine content significantly increased in the high- and low-dose groups ($P<0.05$). No significant differences in the body weight, body length and other nutritional indexes were found between the taurine feed groups and the control group ($P>0.05$). It can be seen that adding a certain amount of taurine to feed could not only reduce the fat content, but also significantly improve the dietary nutritional value of carp[11–13].

2.4.3 Effects of vitamins and minerals on carp growth. Minerals and vitamins are indispensable nutrients in fish life, and the content is generally 3% – 5%. They can not be synthesized in the body, and can not be converted to replace each other, and must be supplied by the outside world. Fish live in water, and they can absorb part of the ions in water through osmosis, diffusion and other ways, but it is far from meeting the needs of the body, and the main source must rely on feed[14–16]. At present, some aquaculture farmers still have doubts about the growth promotion effect of adding these two types of substances in feed, and feed manufacturers also have disputes about how to add these two types of substances in an appropriate ratio.

Taking Jian carp as the study object, 3 × 3 two-factor experimental design[17–18] was adopted, and 9 experimental diets were prepared by adding 0, 62.5 and 185.5 mg/kg vitamin E (VE) to the basic diet and 0%, 0.5% and 1.5% DHA for each vitamin E level, respectively, so as to discuss the effects of adding different levels of vitamin E and DHA to diet on the performance, feed utilization and disease resistance of Jian carp. The results showed that the addition of vitamin E had no significant effect on the specific growth rate of each group ($P>0.05$). The addition of DHA significantly affected the specific growth rate of carp ($P<0.05$), and the specific growth rate of carp was significantly higher than that of control group ($P<0.05$), but there was no significant difference between 0.5% and 1.5% groups ($P>0.05$). The interaction between vitamin E and DHA had no significant effects on the performance and feed utilization of carp ($P>0.05$). The results showed that under the experimental conditions, the addition of DHA in carp's feed had a positive effect on its growth, and vitamin E and DHA had obvious synergistic protective effects on carp's disease resistance[19]. The addition of vitamin E could enhance the resistance to disease, but the effect on growth was not obvious, and excessive addition did not promote the growth of carp[20–21].

3 Research prospects

Although some progress has been made in the study of fish protein nutrition physiology in recent years, it is still not systematic and perfect. Future research should focus on the following aspects: (i) test methods and evaluation criteria should be constantly standardized to improve the reliability and comparability of research results; (ii) the requirement data of basic nutrients such as protein, energy and amino acids should be further improved, and then replacing fish meal protein with animal and plant protein sources is studied; (iii) through modern biotechnology such as fermentation and enzyme preparations, new feed additives or feed processing technologies should be developed to improve the protein utilization rate of fish and reduce ammonia nitrogen excretion; (iv) it is needed to actively explore and practice scientific research results to feed industrialization, so as to promote efficient and green compound feed as soon as possible.

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state. Li Huan *et al.* [14] studied the interaction between earthworms and mycorrhiza and its effects on corn's absorption of nitrogen and phosphorus in soil. The interaction between earthworms and mycorrhiza increased the biomass of aboveground and underground parts of corn, and the absorption of nitrogen and phosphorus increased the content of carbon and nitrogen, *etc.* in soil microbial biomass. Zhou Dongxing *et al.* [15] studied the degradation effect of polyacrylamide in soil by the synergistic effect of earthworms and bacteria, and found that whether only earthworms or bacteria were added, or both earthworms and bacteria were added, it could significantly promote the degradation of PAM in soil and the synergistic effect of earthworms and bacteria on the degradation of PAM in soil was the best. The bioturbation of earthworms in soil made the soil mix continuously, which was conducive to the spread and diffusion of microorganisms and increased the chance of contact between microorganisms and pollutants.

4 Conclusion

Greenhouse cultivation is an irreplaceable production mode to effectively improve unit output value under the condition of land shortage, but the deterioration of soil quality caused by greenhouse cultivation restricts the sustainable development of this production mode. The combination of earthworms and biological agents can improve the environmental quality of soil in greenhouse cultivation and improve the quality of crops. Mature soil remediation technology with earthworms and biological agents will be widely used and popularized in highly intensive agriculture and forestry practice, so as to better improve the social benefits of intensive production.

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