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Analysis of Feed Formulations for Carp Used in Fishery Farms of Tashkent Region

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ABSTRACT

The article examined the sensory attributes of carp feed—such as odor and color—which should be consistent with the raw materials used in production. It emphasizes a minimum shelf life of six months and outlines specific swelling times tailored to different feed types. Feed classification is based on nutritional composition, including protein, starch, fat, and fiber content, with detailed quality benchmarks provided for various rearing conditions, including cages, ponds, and natural water bodies. Additionally, the article includes tables for calculating feed requirements based on fish size, weight, water temperature, and seasonal fluctuations in natural food availability. Overall, the article serves as a comprehensive reference for the formulation and quality assessment of carp feed, aimed at promoting optimal fish growth and health.

INTRODUCTION

The aquaculture industry has seen significant growth in recent years, with carp being one of the most widely cultivated fish species worldwide. The success of carp farming heavily relies on the quality of feed used, which plays a crucial role in the growth, health, and overall productivity of the fish. To ensure that the nutritional needs of carp are met, it is essential that compound feeds adhere to established standards and regulations, particularly those set forth by GOST (Russian National Standards).

This article aimed to provide a comprehensive overview of the characteristics and requirements of compound feeds specifically formulated for carp. It highlighted the importance of durability, water resistance, and nutritional balance, which are fundamental for maintaining feed quality and preventing spoilage. The discussion covered the optimal

particle sizes and shapes of the feed, the significance of sensory attributes such as odor and appearance, and the critical parameters for moisture content and shelf life.

Additionally, the article delved into the classification of feeds based on their nutritional composition, including protein, starch, fat, and fiber content, as well as the necessary vitamin levels. By presenting detailed quality indicators and guidelines for calculating feed requirements, this article aimed to serve as a valuable resource for aquaculture practitioners seeking to optimize their feeding strategies and enhance the growth performance of carp in various farming environments. Through adherence to these standards, fish farmers can ensure sustainable practices and improved outcomes in carp aquaculture.

For a more detailed analysis of carp feeding in aquaculture pond farms of the Tashkent region, it is essential to examine the formulations of compound feeds that were used during the studies.

The main goal of the experiments is to contribute valuable knowledge that supports the development of high-quality, nutritionally balanced feeds specifically tailored for carp aquaculture.

In these farms, carp were raised using two methods during the experiments:

- **Semi-Intensive Method:** This approach involves the use of compound feeds, but in limited quantities. It allows carp to receive additional nutrients, which promotes their growth and development; however, the main part of their diet still consists of natural food, such as plankton and algae.
- **Extensive Method:** In this case, carp are raised in conditions close to natural ones, with minimal use of compound feeds. The fish rely on natural feeds, which may lead to slower growth but also reduces feed costs.

The formulations of compound feeds used in carp farms typically include a variety of components, such as grains (e.g., wheat, corn), legumes (e.g., soybeans, peas), fats (e.g., vegetable oils), mineral additives (e.g., phosphorus, calcium), as well as essential vitamins and trace elements. Achieving the correct ratio of these components is crucial for promoting optimal growth, health, and feed efficiency in carp. Key considerations in feed formulation include digestibility, the proportions of proteins, fats, and carbohydrates, the balance of amino acids, and the adequate inclusion of essential trace elements.

MATERIALS AND METHODS

Research object

The object of this study was one-year-old carp (*Cyprinus carpio*), selected to evaluate the impact of compound feed on growth and development.

Compound feed

The feed used was of domestic origin, produced in the Republic of Uzbekistan, and specifically formulated for one-year-old carp.

Research collaboration

The quality assessment of the feed was carried out under an agreement between the Scientific Research Institute of Fish Farming (under the Committee for Veterinary and Animal Husbandry Development of the Republic of Uzbekistan), the Republican Unitary Enterprise "Institute of Fish Farming," and the RUP "Scientific and Practical Center of the National Academy of Sciences of Belarus for Animal Husbandry."

Experimental setup

The research was conducted in the "Feeds and Feeding" laboratory under the supervision of Candidate of Technical Sciences, Associate Professor Koshak Zh.V., as well as in the laboratory complex of the Scientific Research Institute of Fish Farming of the Republic of Uzbekistan.

Analytical methods

The quality of compound feeds and fish muscle tissue was analyzed using standardized and widely accepted methodologies in accordance with current national and international standards:

- **Crude protein content**: Kjeldahl titrimetric method (**GOST 13496.4-93**).
- **Fat content**: Extraction using a Soxhlet apparatus (**GOST 13496.15**).
- **Moisture content**: Determined by drying to a constant weight (**GOST 13496.3**).
- **Ash content**: Dry ashing method (**GOST 26226-95**).
- **Crude fiber**: Determined by removal of acid- and alkali-soluble substances (**GOST 13496.4**).
- **Peroxide value**: Assessed according to **GOST 31485-2012**.
- **Acid value**: Determined by **GOST 13496.18-85**.
- **Protein, moisture, and fat in fish muscle tissue**: Analyzed according to **GOST 31795-2021**.
- **Micro- and macroelements**: Assessed based on **GOST 26929-94**, **GOST 28901-91**, **GOST 30502-97**, and **GOST 32345-2013**.
- **Vitamins**: Evaluated using **GOST 30627.4-98**, **GOST 7047-55**, **GOST EN 14152-2013**, **MVI.MN 2052-2004**, **GOST R 54635-2011**, and **STB EN 12822-2012**.
- **Carotenoid content**: Extracted using acetone as the organic solvent (**ISO 11052:1994**, **GOST 13496.17-2019**).
- **Carbohydrate content**: Determined according to **GOST 26176-91**.

RESULTS

The study of compound feed formulations used in fish farming enterprises in the Tashkent region provides valuable insights into current feeding practices for carp and helps identify opportunities to optimize diets for improved fish health and productivity. To ensure a more accurate and comprehensive analysis, it is essential to include the data presented in Table (1), which outlines specific feed formulations, their component composition, and the percentage ratios of each ingredient. This information enables a detailed evaluation of the nutritional value of the feeds and their suitability for meeting the dietary requirements of carp under different farming systems.

Table 1. Formulations of domestically produced compound feeds for carp

Composition	Percentage of raw material, %	Compound feed for pond fish (intensive feeding) No. 1	Compound feed for pond fish (intensive feeding) No. 2
Soy concentrate	5.00	5.00	
Fish meal	2.00	-	
Hydrolyzed feather meal	12.00	6.00	
BKS (Balanced Compound Feed)	28.00	21.00	
Wheat	34.00	35.00	
Corn	5.00	5.00	
Tricalcium phosphate	0.75	-	
Premix	1.25	1.00	
Fish oil	2.00	-	
Wheat bran	10.00	25.00	
Shell	-	2.00	
Total:	**100.00**	**100.00**	

Two compound feed formulations from a domestic producer, used in 2021, were analyzed to assess their nutritional adequacy for carp farming. The analysis of these formulations (Table 1) revealed the presence of certain components potentially unfavorable for carp health and growth.

One such component is hydrolyzed feather meal, which contains the protein β-keratin. This protein has low digestibility in fish—ranging from only 37% to 49%—and presents a notable amino acid imbalance. Specifically, essential amino acids such as histidine and lysine are found at levels 7 to 9 times lower than recommended. Experimental data confirm the poor digestibility of feather meal, which contributes to stunted carp growth and metabolic disturbances.

The overall digestibility of feather meal ranges from 45 to 58%, meaning a substantial portion of the ingested protein is not metabolically utilized. The amino acid deficiencies are as follows:

- **Histidine**: 9-fold deficiency
- **Lysine**: 7-fold deficiency
- **Leucine and Isoleucine**: 1.5 to 1.8 times below required levels

Such deficiencies can lead to:

- Poor growth and development
- Immune system dysfunction
- Disrupted nitrogen metabolism due to amino acid imbalance

Given these concerns, it is essential to **re-evaluate the amino acid profile** of compound feeds and supplement them with **alternative protein sources** or amino acid additives rich in histidine and lysine. Protein ingredients with **higher bioavailability** should be prioritized.

Nutritional characteristics of other feed components

Wheat is commonly used in carp feed and has the following characteristics:

- **Protein content**: 6–22%, but deficient **in lysine and methionine**
- **Carbohydrates**: 65–82%, with a high starch concentration
- **Anti-nutritional factors**: Contains trypsin inhibitors, phytates, and potential toxins if improperly stored

Although heat treatment can eliminate fungal contamination, mycotoxins remain stable and pose a risk to fish health. Digestibility studies show:

- **Wheat protein digestibility**: 80–84%
- **Carbohydrate digestibility**: 58–64%
- **Overall digestibility**: 51–65%

Soy protein concentrate is another feed component with up to 68% protein content, making it a valuable source of essential amino acids. The inclusion of vegetable oils (2–6%) is also recommended to meet the fat requirements in carp diets.

Nutritional strategy and feed efficiency

Effective carp feeding requires careful selection of feed components, considering:

- Digestibility
- Amino acid composition
- Macro- and micronutrient balance

Limiting the inclusion of poorly digestible ingredients such as feather meal and ensuring the quality control of wheat, corn, and other grains will support a nutritionally balanced diet and improve fish health.

Feed costs are directly influenced by feed quality and external environmental factors. Variables such as low water temperatures, poor hydrochemical conditions, and fish diseases reduce feed utilization efficiency. Moreover, feed conversion rates increase with fish age.

For the standard compound feed formulation PK-110-1, feed conversion ratios (FCR) are provided as follows (in kg feed per kg weight gain):

Age	Weight Gain, kg
Fingerlings	2.5 - 3.0
Two-year-olds	3.3 - 3.5
Three-year-olds	4.0 - 4.5
Four-year-olds, Five-year-olds	5.0 - 6.0
Breeders	8.0 - 9.0

An important indicator of the condition of breeding carp is their growth, measured in grams:

Age	Weight Gain, g
Fingerlings	45 - 100
Two-year-olds	500 - 1300
Three-year-olds	1400 - 2500
Four-year-olds	2200 - 3500
Five-year-olds	3000 - 4500
Six-year-olds	3500 - 5500

The annual individual weight gain of broodstock carp should range between 1.0 and 1.5kg under optimal feeding and environmental conditions.

Feeding practices must consider the oxygen regime in the ponds, especially during the peak feeding season (July–August), when high water temperatures and increased organic matter accumulation can lead to oxygen depletion. During this period, feeding should be carried out no earlier than 2–3 hours after sunrise, when oxygen levels are generally higher and should not fall below 2.5–3.0mg/ L.

If the average daily oxygen concentration in the water falls to 3–4mg/ L (with early morning values between 1.5–2.5mg/ L), it is recommended to reduce the feeding rate by 5% to prevent stress or health deterioration. In cases where fish show pre-morbid symptoms or mortality occurs, feeding must be suspended immediately and resumed only when oxygen levels stabilize within safe limits.

Feeding frequency depends on both the daily feed allowance and water temperature:

- For fingerlings, feeding should occur 1 to 4 times per day.
- For two-year-old carp, feeding should be limited to 1 to 3 times daily.

During feeding, close monitoring is essential. If feed is consumed very quickly, it may indicate underfeeding. Conversely, if uneaten feed remains for more than 3 hours, it may suggest overfeeding, which can lead to water quality deterioration and wasted feed resources.

Table 2. Feeding frequency varies depending on water temperature

Temperature (°C)	10-16	17-21	21-25	25 and above
Feeding Frequency	1	2	3	3-4

Seasonal feeding guidelines and compound feed requirements for carp (*Cyprinus carpio*)

Feeding schedule and seasonal adjustments

In the autumn period, when water temperature drops to approximately +18°C, single daily feeding of carp is considered sufficient. However, feeding times and frequency should be adjusted according to seasonal conditions and feeding strategies:

- **Single feeding:** Recommended between 9:00 AM and 11:00 AM

- **Double feeding:**
    - First feeding: 6:00 AM – 9:00 AM
    - Second feeding: 3:00 PM – 5:00 PM
- **Multiple feedings (four times daily):**
    - First portion: 6:00 AM – 8:00 AM
    - Second portion: 10:00 AM – 11:00 AM
    - Third portion: 1:00 PM – 3:00 PM
    - Fourth portion: 5:00 PM – 7:00 PM

To ensure optimal digestion and feed utilization, maintain intervals of at least 3–4 hours between feedings. Additionally, daily feed allowances should be gradually reduced as the fish grow, in alignment with their changing metabolic demands.

Daily feed allowance calculation

The daily feed requirement for a pond or water body is calculated using the following formula:

$$S=R\times A\times n/100$$

Where:

- **S** = Daily feed allowance (g)
- **R** = Average weight of the fish (g)
- **A** = Daily feed allowance as a percentage of fish weight
- **n** = Number of fish in the water body

Compound Feed Quality Standards

Compound feeds used in carp aquaculture must comply with **GOST standards** and established **technical conditions**. The key quality characteristics are as follows:

- **Durability and Water Resistance:** Feeds must remain intact in water for specified periods to minimize nutrient loss.
- **Nutritional Balance:** Must be complete and balanced in essential proteins, fats, carbohydrates, vitamins, and minerals.
- **Particle size and shape**
    - Particle size: 0.1–3mm
    - Pellet diameter: 3–12mm
    - Pellet length: 1.5–3 times the diameter
    - Shape: Cylindrical or oval, with smooth, polished surfaces free of cracks.
- **Feed Homogeneity:** The final product should be uniform, with no visible mold, discoloration, or contamination.
- **Odor and Color:** Should reflect the original raw materials.
    - Fish meal: Dried fish scent
    - Herb meal: Hay-like smell
    - Must be free from musty or moldy odors

- **Moisture Content:** Should not exceed 14.5% to prevent fungal growth and pest infestation.
- **Shelf Life:** Minimum of 6 months under proper storage conditions.
- **Swelling time:**
    - Sinking production feeds: ≥20 minutes
    - Floating or slow-sinking feeds: ≥30 minutes
    - Starter feeds: ≥10 minutes
- **Water Resistance and Shape Retention:** Minimum of 3 hours in water.
- **Crumb Loss (Mechanical Durability):** Should not exceed 8% during handling, transport, and storage.

Classification of compound feeds

Feeds are categorized based on key nutritional parameters:

- **High-protein feeds:** >23% protein
- **Low-protein feeds:** <23% protein
- **High-starch feeds:** >36% starch
- **High-fat feeds:** >8% fat
- **High-fiber feeds:** >11% fiber

Vitamin levels (A, D, E, B_1–B_6, B_{12}, C) are formulated according to the premix specifications used in the feed recipe.

Table 3. Size Groups of carp

Size Groups	Condition Factor of Carp
20 g and above	2.4
Between 20 g and 10 g	2.6
10 g and below	2.8

The calculation of the amount of feed required for carp should be conducted using special tables designed for each age group. The basis of the calculation is the relationship between daily rations, fish weight, water temperature, and seasonal changes in the proportion of natural food in the diet.

Table 4. Quality indicators of feeds

Name	Indicators
	Carp
	Cages and Ponds
Metabolizable energy, not less than, kcal/kg	3100-3400
Crude protein, not less than, %	34-38
Crude fat, not less than, %	6-9
Fiber, not more than, %	4.5-8
Ash, not more than, %	10

Phosphorus, not less than, %	0.8
Lysine, not less than, %	1.3
Methionine + Cystine, not less than, %	
Calcium, not less than, %	

Feed calculations are carried out with consideration of the development of the natural food base in the ponds. To account for seasonal variations in natural food availability, the entire growing season is conventionally divided into three periods. The first period varies in duration depending on the climatic zone and typically lasts 1 to 3 ten-day intervals (decades). If the natural food base is found to be poorly developed during this initial stage, it may be excluded from the feeding calculation. In such cases, feed planning is conducted based on the main feeding period, followed by the final period, which generally occurs in September.

DISCUSSION

An analysis of the formulations presented in Table (1) reveals several physiologically unfavorable characteristics for carp (*Cyprinus carpio*) associated with both Recipe No. 1 and Recipe No. 2. Notably, both include hydrolyzed feather meal as a protein source. While feathers represent a significant by-product of the poultry industry, they are composed primarily of β-keratin, a structural protein that is nearly indigestible in the gastrointestinal tract of animals unless subjected to specialized hydrothermal or chemical treatment.

Although feather meal is rich in sulfur-containing amino acids such as cysteine and methionine—typically limiting in conventional feed ingredients—it suffers from low overall digestibility. According to **Barta *et al.* (1984)** and other studies, the digestibility of protein from feather meal in vitro ranges between 37 and 49%, and the overall digestibility of the product varies from 45 to 58%.

In addition to low digestibility, feather meal has critical amino acid imbalances, particularly:

- Histidine: up to 9 times lower than carp nutritional requirements
- Lysine: 7 times lower
- Phenylalanine, leucine, and isoleucine: 1.5 to 1.8 times lower

This imbalance disrupts the nutritional profile of the feed, resulting in metabolic inefficiencies and reduced growth performance. According to **Shcherbina *et al.* (2004)**, the digestibility of extruded feather meal protein in carp remained around 45%, while the lipid fraction (4.4%) was utilized at only 27%. Furthermore, analysis of ash element balance showed higher endogenous excretion compared to dietary absorption, indicating a mismatch between mineral composition and the fish's physiological needs.

The nutritional and metabolic consequences of feather meal inclusion in carp diets include:

- Stunted growth and low feed conversion efficiency
- Dehydration of tissue, suggesting disrupted osmoregulation
- Suppressed anabolic processes and a shift toward catabolism, contributing to cellular degradation and premature tissue aging

These effects reflect a low biological value of feather meal for carp. Experimental data show that the bioavailability of critical amino acids from feather meal is poor:

- Histidine: 11%
- Lysine: 14%
- Phenylalanine: 56%
- Isoleucine: 65%

Following Liebig's Law of the Minimum, even the high levels of methionine and cysteine are insufficient to compensate for the severe deficiency in other essential amino acids.

Cho (1993) reported higher feather meal digestibility for trout—with crude protein digestibility up to 58%, dry matter digestibility at 75%, and energy digestibility at 70%—likely due to species-specific digestive capabilities. This highlights interspecies variability in nutrient utilization and the importance of tailoring feed formulations to the target species.

Similarly, in a review by **Vladovskaya (2002)**, the inclusion of hydrolyzed feather meal in diets for the African catfish led to a marked reduction in growth rate, especially as the proportion of fish meal replaced by feather meal increased.

Recommendations

Based on the evidence, the use of feather meal in carp diets should be limited to 4–7% of the total formulation. This level may be acceptable when paired with other protein sources rich in lysine and histidine, such as soybean meal, feed yeast, or blood meal, to correct the amino acid imbalance.

In Recipe No. 1, however, the inclusion rate of feather meal is 12%, approximately 2.5 times higher than recommended. This level significantly exceeds the threshold at which feather meal begins to negatively impact digestibility, nutrient absorption, and fish growth, thus reducing the feed's effectiveness and potentially compromising fish health.

CONCLUSION

Based on the research conducted, the following conclusions can be drawn:

- Compound feed formulations produced in Uzbekistan were analyzed and found to exceed the maximum allowable limits for certain ingredients. These deviations

highlight the need to revise and optimize feed formulations in alignment with the nutritional requirements and physiological capabilities of carp.

- A protein deficiency was identified in the compound feeds intended for market-size carp at water temperatures of 28–30°C. The protein content was found to be approximately 4.5% below the required level, leading to a marked decrease in growth rates and reduced efficiency of carp cultivation. In contrast, the levels of crude fat and crude fiber in all tested feed samples conformed to the recommended norms as specified in GOST 10385-2014: "Compound Feeds for Fish. General Technical Conditions."
- The analyzed compound feeds were also found to be imbalanced in essential amino acids, including lysine, threonine (in both market and small intensive feeds), methionine, cysteine, and the combined levels of phenylalanine and tyrosine. Notably, the total requirement for methionine and cysteine was met by only 1.11% in the studied samples. This severe deficiency compromises the bioavailability and absorption of other amino acids, further limiting the nutritional efficiency of the feed.

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