Original Contribution

NET ENERGY AND PROTEIN UTILIZATION IN FISH BY INTRODUCING THE OBJECTIVE CRITERIA “CLARC OF ENERGY DISTRIBUTION” AND „CLARC OF PROTEIN TRANSFORMATION“

D. Penkov^{1*}, T. Hubenova², A. Ivanova²

¹Agricultural University, Plovdiv, Bulgaria

²Institute of Fisheries and Aquaculture, Plovdiv, Bulgaria

ABSTRACT

AIM: To introduce the indicators Clarc of energy distribution (CED) and Clarc of protein/amino acid transformation (CPT) and adapt the methodology for their calculation in aquaculture. **MATERIAL AND METHODS:** A 50-day experiment was carried out with juvenile carp fish (*C. carpio* L.) reared in net cages. The following characteristics were reported: fodder (nutritional) coefficient, digestible energy, and crude protein intake per unit of weight gain, percentage of the boneless fillet, the chemical composition of the fillet. The methodology for calculating the respective Clarcs was described. **RESULTS:** The following values of the newly introduced indicators were established: Clarc of energy distribution (CED) – 0.0866 (8.66%); Clarc of protein transformation (CPT) – 0.1052 (10.52%).

Key words: Aquaculture, Clarc of energy distribution, Clarc of protein transformation

INTRODUCTION

One of the major efficiency indicators in fish farming is proper feeding. On the one hand, the exact energy and nutrient requirements of the various types of fishes should be identified and, on the other, the use of the appropriate combination of forage and additives to meet those needs.

Currently, digestible energy is used as an indicator of the energy nutritional value of fish feed (1, 2). The energy nutritional value of feed in Bulgaria is determined by the equation (3) calculating the forage digestibility in experiments with poultry (4).

Although there are data of nitrogen digestibility of fish feed (2), crude protein and amino acid contents are used as an indicator of the protein nutritional value of forages.

Another significant indicator of the nutritional value of fish feed is the protein ratio, which is equal to the ratio of crude protein to crude fat multiplied by 2.3 + nitrogen-free extracts (4, 5).

***Correspondence to:** Dimo Penkov, Agricultural University – 4000 Plovdiv, Bulgaria, 12 D. Mendeleev Str., dimopenkov@gmail.com

The term ‘feed coefficient’ (“feed conversion ratio”), representing the ratio between the dry matter intake from feed per unit of live weight gain of fish, is used as an indicator of the feed utilization efficiency in aquaculture (2).

Modern concepts of healthy nutrition require clearer definitions of the energy and nutrient conversion from feed to livestock and on that basis – the development of more optimal feeding rations, which, on the one hand, decrease the nutrient losses and, on the other, increase the production efficiency by reducing feed consumption per unit of production. That could be achieved by finding new ways to accurately determine the net energy and nutrient utilization in the body (6, 7).

In 2018, a new approach was proposed to calculate the net energy and protein/amino acid utilization by introducing the Clarc of energy distribution (CED) and the Clarc of protein/amino acid transformation (CPT), which shows the energy and nutrient ratios accumulated in the dry matter of the human-edible products of animal origin (meat, milk, eggs), (8). The concepts and methodology for calculating the respective indices were

borrowed from the ecology of heavy metals and their transformation from primary to a secondary level of the ecological pyramid (9, 10).

The aim of the present study was to introduce the indicators Clarc of energy distribution (CED) and Clarc of protein/amino acid transformation (CPT) and to propose a methodology for their calculation in fish farming.

MATERIAL AND METHODS

Data from the experiments carried out in 2017 – 2019 at the Institute of Fisheries and Aquaculture – Plovdiv were used to calculate the indicators.

Biological experiment: Net cages, $1.0 \times 1.0 \times 1.0$ m in size (working volume of 0.6 m^3), located in an earth pond, and were stocked with carp fishes at a stocking density of 60 fish per cage. After 7 days of adaptation and feeding, the fish were fed on extruded fodder for 50 days. Control tests on the live weight of fish were conducted every 10 days and the feed supply was adjusted. The daily feed ratio was 7% to 12% of the live weight of fish and it was supplied to the automatic feeders 4 times a day, every 3 hours. The experiment was performed in 3 replications (3 cages).

The feed was produced at Bonmix – Lovech Company. Ingredients: wheat, maize, maize gluten, fish meal, stabilized vegetable fat, vitamin and mineral premix. Nutritional value: Moisture – 7%; Digestible energy, fish (1) – 14.43 MJ; Crude protein – 32.62%; Crude fat – 10.94%; Crude fiber – 3.26%; Non protein extract – 32.88%; Ash – 13.3%; Potassium – 1.42%; Phosphorus – 1.25%; Chloride – 0.40%.

At the beginning and at the end of the experiment a morphological analysis of the carcass of 3 fish per cage, having a live weight closest to the average, was conducted to determine: carcass weight (eviscerated), percentage of head, tail, and fins, and boneless fillets.

The fillet was boned by pre-boiling and separation of the bones (vertebrae and ribs).

At the end of the experiment, a complete chemical analysis of 3 averaged native fillet samples was performed (11).

The gross energy content of the fillet was calculated using the formula (12):

$$GE(MJ)=0.0242*CP+0.0366*CFats+0.0170*NPE \quad [1]$$

The Clarc of energy distribution (CED) the Clarc of (crude) protein transformation (CPT) were calculated according the formula of (8):

$$CED = GE \text{ (fillet)} / DE \text{ (fodder)} \quad [2]$$

$$CPT = CP \text{ (fillet)} / CP \text{ (fodder)}, \text{ where:} \quad [3]$$

GE and CP (fillet) – gross energy content (J) and crude protein content (g) in the fillets of the experimental fish, boneless*

DE and CP (fodder) – the digestible energy (J) and crude protein (g) consumed by fish for the whole experimental period.

*The fillet weight was calculated as the difference between the final and the initial weight at the beginning of the experiment.

RESULTS AND DISCUSSION

Table 1 presents the consumption of fodder, gross energy and crude protein by the experimental fish throughout the study period.

Table 1. Fodder (g), digestible energy (kJ) and crude protein consumption (g) for the whole experimental period (50 days – entrance of the system) – mean from 3 replications

No	Indices (mean of one cage)	X mean	SE
1	Total fodder consumption – g	2870	433
2	Total digestible energy consumption – kJ	41414.1	6248
3	Total crude protein consumption – g	936.19	141

The total feed consumption rate reported by us, was comparable to that reported in similar studies on carp, conducted in Bulgaria, i.e. from 1440 to 3350 grams (13, 14).

Table 2 presents the initial and final weight of fish, as well as the average individual and total growth per cage.

Table 2. Growth, survival and feed conversion ratio during the experiment (mean of 1 fish and 1 cage)

Indices	X mean	SE
Mean live weight of 1 fish – beginning of the experiment, g	13.11	0.528
Mean live weight of all the fishes – beginning, g	786.6	31.68
Mean live weight of 1 fish – end of the experiment, g	29.08	1.88
Mean live weight of all the live fish – end of the experiment, g	1715.82	110.92
Average individual weight gain of survived fish, g	15.97	1.20
Average total weight gain per cage, g	929.22	70.80
Mean % of survival	98.33	
Fodder (nutritional) coefficient (Feed conversion ratio)	2.78	

The results obtained in the present study were comparable to those obtained by other authors (15-17).

Table 3 presents the morphological indices needed for the calculation of the Clarks of the experimental fish at the end of the study period.

Table 3. Some morphological indexes of fishes after the 50-day experimental period (mean value of 1 fish and 1 cage)

No	Indices	X mean	SE
1	Mean eviscerated weight of a fish at the end of the experiment, g	24.09	1.57
2	Mean eviscerated weight of all the fishes in one cage at the end of the experiment, g	1421.39	92.05
3	Mean head weight, g	4.50	0.31
4	Mean weight of fins and scales of a fish, g	1.05	0.07
5	Mean weight of fillet bones of a fish, g	0.87	0.01
6	Mean weight of the boneless fillet of a fish at the end of the experiment, g	17.67	1.04
7	Mean weight of the boneless fillet of all the fishes in one cage at the end of the experiment,	1042.53	76.50
8	% of boned fillet to the final live weight	60.76	-
9	Mean weight of boneless fillet of all the fishes in one cage at the beginning of the experiment (= mean initial live weight of all the fishes in the cage at the beginning of the experiment * % of boneless fillet to the final live weight), g	477.94	31.88
10	Recalculated fillet weight gain of all the fishes in one cage for the experimental period, g (= row 7 – row 9), g (kg)	594.59 (0.59459)	34.12 (0.034)

The mean weights of head and of fins and scales, obtained in the present study, were quite similar as a percentage of the body weight, to the values reported in other studies with one- and two-year-old carp (18). The percentage of the fillet bones was relatively lower due to the fact that the vertebrae and ribs of the experimental fingerlings were of lower weight due to the low final live weight.

Based on the data obtained from the experiment, the following calculations were required at the system output (cumulative gross energy and crude protein in boneless fillets), presented in **Table 3**:

1. The morphological analysis of at least 5% of the experimental fish with weight as close to

the average as possible, was conducted, measuring the weight of the intestines, head, tail, ribs and bones in the fillet – row 3 + row 4 + row 5 of **Table 3**.

2. The percentage of the clean fillet was calculated as the difference between 100% and the sum of the percentages of the measured non-edible parts listed in item 1.

3. The percentage of the fillet to the mean weight of 1 fingerling at the end of the experiment (row 6 in Table 3) was calculated.

4. The mean weight of the fillet of all the survived fingerlings at the end of the experiment was found (row 7 in **Table 3**) = row 6 of **Table 3** × the number of fingerlings survived in the cage.

5. Provided that the initial live weight of a fingerling is less than 20 grams (the fish were small in size and that complicated their morphological analysis), the initial weight of the fillet was calculated by multiplying the initial live weight of 1 fingerling by the percentage calculated according to item 3, **Table 3**.

When the experiments are carried out on biannual and larger in size fish, the calculation of the initial percentage of the fillets of one fish is performed as described in items 1 to 4.

6. It is necessary to calculate how much of the fillet was obtained in result of the weight gain during the experimental period (row 10, Table 3) – that is the weight output of the eco-technical system.

At the end of the experiment it was established that during the experimental period the survived fish had accumulated 594.59 grams as clean fillets (boneless).

In order to calculate the output of the eco-technical system, data on the chemical composition of the fillet, is also needed (**Table 4**).

Table 4. Weight, chemical and energy composition of the boneless fillet of the fishes, object of the experiment, and Clarcs of energy distribution (CED) and (crude) protein transformation (CPT)

No	Indices	X mean	SE
1	Dry matter content, %	23.67	0.06
2	Crude protein content, %/g	16.56/165.6	0.20/2
3	Crude fat content, %/g	5.23/52.3	0.23/2.3
4	Ash content, %	1.39	0.09
5	Non protein extract (NPE) content, %/g	0.49/4.9	0.01/0.1
6	Gross energy content (calculated acc. (12), kJ*kg ⁻¹)	6005	260
7	Gross energy content in the fillet weight gain (= row 10, Table 3*line 6, table 4), kJ	3603	110
8	Crude protein content in the fillet weight gain (= row 10, Table 3*row 2, Table 4), g	98.47	0.16
9	Clarc of energy distribution (fodder–fillet weight gain)	0.0866 (8.66%)	
10	Clarc of (crude) protein transformation (fodder–fillet gain)	0.1052 (10.52%)	

Calculations continued, based on the data in **Table 4**:

7. According to the chemical composition of the fillet (rows 2, 3 and 5 of **Table 5**), the gross energy content in 1 kilogram of fillet (native) was calculated.

8. According to the data of the fillet weight gain in kg for the experimental period (row 10 in Table 4) and the gross energy and crude protein content in 1 kg fillet, the gross energy and crude protein accumulated for the whole experimental period were calculated (row 7 and row 8 in **Table 5**).

9. Clarcs of distribution/transformation are quotients of the output of the eco-technical chain (row 7 and row 8 of Table 5, respectively) and the entrance (row 2 and row 3 of **Table 1**, respectively).

CONCLUSIONS

For the entire 50-day experimental period, the annual carp fish consumed an average of 2870 g of compound feed, 41414.1 kJ digestible energy and 936.19 g of crude protein per cage (initially stocked with 60 fishes in each cage).

The calculated fodder coefficient (according to (2) was 2.78 kg/kg of weight gain, i.e. feed utilization was 36%. However, the non-edible parts of the fish were also included, as well as the water content in them.

When recalculating net energy and protein utilization from feed to boneless edible fillet without water in it, the following Clarcs of distribution/transformation were obtained:

- Clarc of energy distribution (Digestible energy fodder – gross energy fillet) – 0.0866 (8.66%).
- Clarc of (crude) protein distribution (crude protein fodder – crude protein fillet) – 0.1052 (10.52%).

We believe that the introduction and calculation of the Clarcs of distribution/transformation objectively reflect the energy and protein transformation from the primary trophic unit (fodder) to the secondary one (human-edible parts) and it is of major importance in 3 directions:

- Ecological – the higher the Clarc values, the lower the energy and nitrogen emissions as pollutants of nature.

- Breeding – the breeding objectives should be targeted at obtaining higher Clarcs of distribution/transformation.

- Technological – fish farming and feeding technologies, which guarantee higher Clarcs of distribution/transformation, should be sought.

In that sense, the proposed methodology for introducing the new criteria will give a fresh start to the research studies in the three directions, without contradicting the old indicators and without significantly complicating the experimental models.

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