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Effects of Dietary Energy Levels on Survival Rates, Growth Performance and Chemical Composition of the Carcass of Juvenile's African Carp *Labeobarbus batesii* (Boulenger, 1903)

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Abstract

In order to contribute to the domestication of Labeobarbus batesii, survival, growth performance in fattening and the chemical composition of the carcass, depending on the food energy level were evaluated. For this purpose, 400 post-fingerlings (mean total length: 28.5 ± 5.2 cm and mean live weight: 127.2 ± 4.8 g) were randomly distributed into four comparable batches, in duplicate. Four experimental isoprotein feed R1, R2, R3 and R4, containing respectively 3600, 3700, 3800 and 3900 kcal of Metabolizable Energy (ME) per kg of Dry Matter (DM) of food, were distributed to the batches described above, at 5% of the ictyobiomass. After 180 days of feeding, the main results obtained are as follows: the survival rate and the values of the chemical characteristics (organic, dry and fatty matter, ash, crude protein, water, HDLC, triglycerides, total protein and cholesterol) significantly elevated ($p<0.05$) were recorded in the groups receiving the food at 3600 kcal ME/kg; while the best growth performances were noted in those fed at 3700 kcal of ME/kg. The condition factor k increased with the increasing energy level in the food and remained greater than 1 throughout the experiment. The carp fed feed at 3600 and 3900 kcal ME/kg showed growth of the allometry-majorant type, while those receiving the feed at 3700 and 3800 kcal of ME/kg had growth of the allometry-minorant type. Thus, food with 3700 kcal ME/kg is recommended for the breeding stock of *Labeobarbus batesii*.

Keywords: Labeobarbus batesii; food energy level; growth in fattening; survival rate; carcass chemical composition.

Introduction

Africa ranks fifth among fish producers in the world ranking, with around 12 million tons reported in 2018 (1) of which 10 million tons come from capture fishing and 2.3 million tons, from aquaculture. That same year, the average per capita fish consumption in Africa was 10 kg/year [1], almost half of the global average (20.5 kg/year). Compared to that recorded in Africa, this average consumption in Cameroon presents a deficit estimated at 2.9 kg/year/inhabitant [2]. Faced with this lack, Cameroon resorts to imports, the quantities of which increase each year and constitute a significant source of foreign currency loss for the country, nearly 114.3 billion in 2017 [3]. Furthermore, galloping population growth has led to overfishing and the destruction of wetlands resulting in a decline in landing stocks [4], despite increasingly sophisticated fishing techniques and gear. Fish farming then presents itself as the most serious alternative to compensate the stagnation of fishing landings and satisfy the growing demand for fish among populations. However, the development of the fish farming sector faces certain constraints, including the lack of quality fry [5], which would be caused by the scarcity of genetic resources adapted to local breeding conditions. This development is accompanied by a diversification of species used in fish farming, based on the domestication of endogenous species. Despite the great diversity of Cameroon's fish species, very few endogenous species such as Clarias jaensis [6,7], Parachanna obscura [8] and Labeobarbus batesii [9,10] have been the subject of domestication studies. Indeed, interest has focused on the African carp Labeobarbus batesii (Boulenger, 1903) of the Cyprinidae family, native to the Mbô floodplain in Cameroon. In addition to being highly appreciated by local populations, this species has proven to be a good candidate for fish farming [11], due to its general morphology (large species) and its growth characteristics (high growth rate) in a natural environment [12]. It is a benthopelagic, omnivorous fish, with a preference for plant and detritivorous material [13]. In a captive environment, the food preferences of this carp at the post-larval stage [9], its protein needs [14] as well as its energy needs [10] in pre-magnification have been studied. However, no information is available regarding the energy requirements of cyprinids in general, or those of *L. barbus* in particular. However, the production of knowledge on its energy needs at the adult stage would undoubtedly contribute to the continuity of its domestication process. Keeping this in mind, this work was carried out with the general objective of contributing to the preservation and enhancement of endogenous fisheries biodiversity, through better knowledge of the nutritional needs of *Labeobarbus batesii*. More specifically, it was a question of evaluating in juveniles of *L. batesii* in captivity, the effect of the metabolizable energy level on:

- The survival rate,
- The growth characteristics and
- The biochemical characteristics of the carcass.

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Material and methods

Period, area and site of the study

The study took place between july and december 2021 at the fish experimental farm of the Institute of the Agricultural Research for Development (IRAD) in Foumban. This farm, located in Koupa Matapit (5°45.826' LN; 10°48.516' LE and 1147 m altitude), is 9 km from the town of Foumban (Western Highlands of Cameroon). The climate is Sudano-Guinean type and includes a rainy season (March – October) and a dry season (November – February). The average temperature and rainfall are respectively 22°C and 1800 mm/year [15].

Animal material

A total of four hundred (400) juveniles of Labeobarbus batesii, with an average weight of 127.2 ± 4.8 g and an average total length of 28.5 ± 5.2 cm, were collected from fishermen in the Mbô floodplain (5° 10' – 5° 30' N, 9° 50' – 10° 10' E; altitude: 700 m). At each collection, the fish were packaged in oxygenated plastic bags, which were packed in boxes with blocks of ice, then transported to the Foumban fish farm. For acclimatization, these juveniles were maintained in happas at a density of 25 fish/m^2 and fed with a standard food containing 25% crude protein [14] for six weeks.

Breeding structure

The test took place in 08 identical happas of rectangular shape, with a volume of 2.304 m^3 (1.80 × 0.80 × 1.60), made of mosquito net with a mesh size of 1.5 mm. These happas were installed in a rectangular pond of 400 m^2, previously prepared two weeks before the start of the test. Preparation consisted of cleaning and disinfection with quicklime (one week before), followed by flooding and fertilizing the pond with chicken droppings (600g/m^2). After labeling, each happa was equipped with a floating plastic frame, below which was placed a basin used to collect food refusals. The pond was equipped with a water supply channel and an overflow discharge pipe, allowing the water level in the happas to be controlled and maintained at a height of 0.90 m throughout the experimentation.

Experimental rations

Depending on the energy needs of Cyprinidae, four experimental isoprotein feed containing respectively 3600, 3700, 3800 and 3900 kcal/kg of DM of food were formulated. To do this, the ingredients used were purchased in local markets, ground, manually homogenized and hydrated (50 cl for 5 kg of food) so as to obtain a homogeneous paste. This paste was then granulated using a mechanical granulator, whose sieve mesh diameter is 6 mm. The granules obtained were then dried in the sun for 24 hours and stored in labeled bags.

The bromatological analysis of each food was carried out after formulation according to [16], at the Animal Nutrition and Food Laboratory of the University of Dschang. The compositions and bromatological characteristics of these feed are presented in (Table 1).

Experimental apparatus

The 400 juveniles were randomly divided into four comparable batches of 100 fishes each. Each batch represents one of the experimental feed R1, R2, R3 and R4, containing respectively 3600, 3700, 3800 and 3900 kcal of ME/kg of food. The 100 fishes were placed in the eight happas described above at a density of 25 fish/m^2. Each happa received at random and in duplicate one of the experimental feed, following a complete randomization system.

Table 1: Composition and bromatological characteristics of experimental feed.

Ingredients	Expérimental feed D			
	R1	R2	R3	R4
Corn	29.00	38.00	32.00	36.00
Remoulding	30.00	19.00	24.00	18.00
Cotonseed meal	15.00	9.00	8.00	4.00
Soybean meal	9.30	10.03	9.30	10.30
Blood meal	2.00	2.00	2.00	2.00
Fis meal	8.00	13.00	14.00	17.00
Shell	0.10	0.10	0.10	0.10
Bone meal	0.10	0.10	0.10	0.10
Palm oil	4.00	6.00	8.00	10.00
Iodized salt	0.50	0.50	0.50	0.50
Premix 2%	2.00	2.00	2.00	2.00
Total	100.00	100.00	100.00	100.00
Bromatological characteristics analyzed				
DM (%)	88.58	88.635	89.03	88.71
Ash (%DM)	6.385	5.835	6.41	5.675
OM (%DM) (kcal/kg)	81.7	82.8	82.535	83.035
CP (%DM)	20.06	20.13	20.28	20.35
Fat (%DM)	9.00	10.715	11.595	16.24
ME (kcal/kg of DM)	**3588**	**3708**	**3820**	**3911**

Conduct of the trial and data collection

During the 6 months of experimentation, the fry were fed twice a day (9 a.m.-10 a.m. and 4 p.m.-5 p.m.) at 5% of the ichthyobiomass. A control fishing was carried out every month during which 20% of the number of each happa was taken randomly using a landing net for body measurements (total length LT, fork length LF, standard length LS and live weight PV), just as at the start of the test. Thus, each fish was weighed individually using a 0.1g precision electronic balance and measured using a millimeter ichthyometer. The measurements collected monthly made it possible to evaluate growth and readjust the quantities of food to be distributed the following month. At the time of food distribution, dead individuals in each happa were removed and counted to assess the survival rate. Food refusals were collected from the basins every week, dried in the sun then weighed using an SF – 400 brand electronic scale to estimate food consumption. At the end of this experiment, all of the individuals were caught in each treatment and then counted in order to determine the survival rate. Fourteen fish were then taken from each batch, transported alive in oxygenated plastic bags to the Physiology Laboratory at the University of Dschang. The measurements of the fish were taken individually and then they were sacrificed.

Characteristics studied

Survival rate

The survival rate was determined using the following formula:

$$Sr = \frac{(Initial\ number\ of\ fishes - Mortality)\ X\ 100}{Initial\ number\ of\ fishes}$$

Growth characteristics

Food consumption (FC): Food consumption was estimated using the following formula:

FC (in g) = Quantity of food served – Refusal

The live weight and lengths (total and standard) collected made it possible to evaluate the following growth parameters:

Weight gain (WG in g) = Final weight - Initial weight

Average daily gain (ADG in g/day) = (Final weight - Initial weight) / Time (number of days)

Specific growth rate (SGR) = ((ln⟦final weigth -ln⟦initial weigth⟧) X 100)/(Time (number of days))

(Ln = natural logarithm)

Length-weight relationship: This was established according to the equation:

PT = a LTb (Le Cren, 1951), with PT = total weight of the fish (g), a = regression constancy, b = regression coefficient, LT = total length (cm).

Consumption index (CI): This characteristic was obtained using the following formula: CI (in g/g) = (Quantity of food consumed)/(Final weight-Initial weight)

Condition factor K: This factor was calculated according to (17)

Formula: K = 100 (TW / (TL) 3), with TW = Total weight (g), LT = Total length (cm).

Biochemical characteristics of the carcass

The dorsal muscles of the sacrificed fish were removed [17] and immediately placed in an incubator at 105°C at the Animal Nutrition and Feeding Laboratory at the University of Dschang. These samples were used to determine the biochemical characteristics (dry matter, proteins, lipids, ash and organic matter) of the flesh, using the methods described by [16].

The ventral muscles of the sacrificed fish were removed [18] and then crushed separately in a mortar placed on a piece of ice. Each ground material obtained was homogenized with 10 mL of physiological fluid (Nacl) 0.9%. The different homogenates were centrifuged at 3000 rpm for 30 minutes using a centrifuge. The supernatant obtained was stored at –20°C in microtubes labeled, for the determination of proteins, total cholesterol, HDL (High Density Lipoprotein) and TGS (Triglycerides) in fish flesh. This assay was carried out using enzymatic colorimetric methods following the instructions for CHRONOLAB commercial kits for total proteins and cholesterol, HDL and tissue TGS.

Statistical analyzes

The collected data were subjected to one-way analysis of variance (ANOVA I). This analysis allowed testing the effect of energy level on survival rate, growth characteristics and carcass biochemical characteristics. When there were significant differences between the treatments, the Duncan test at the 5% significance level was used to separate them. Correlations were made to reveal the level of association between the characteristics studied. "Power" regression was used to determine the allometry coefficient and the growth type. SPSS version 22.0 software was used to perform these analyses.

Results

Survival rate of Labeobarbus batesii depending on the food energy level

The survival rate depending on the food energy level in juveniles of *L. batesii* is illustrated in (Figure 1). It appears that survival was significantly ($p<0.05$) affected by the food energy level. Additionally, carp fed the lowest food energy level showed the highest values, while those fed the highest food energy level showed the lowest values.

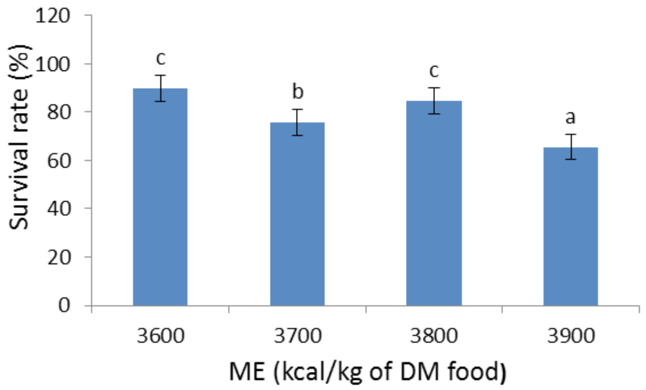

Figure 1: Survival rate depending on the food energy level in *L. batesii*.
ME = metabolizable energy; **DM** = dry matter; (**a, b, c**): histograms bearing the same letter are not significantly different (p>0.05).

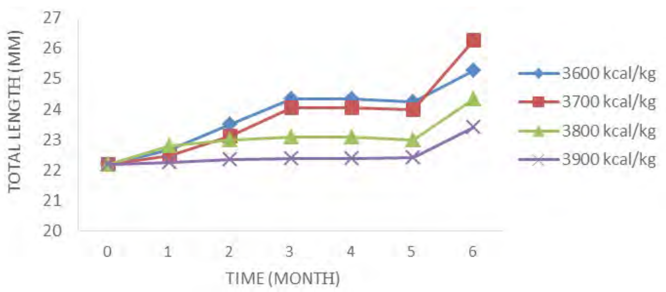

Figure 2: Evolution of the total length of *L. batesii* depending on the food energy level.

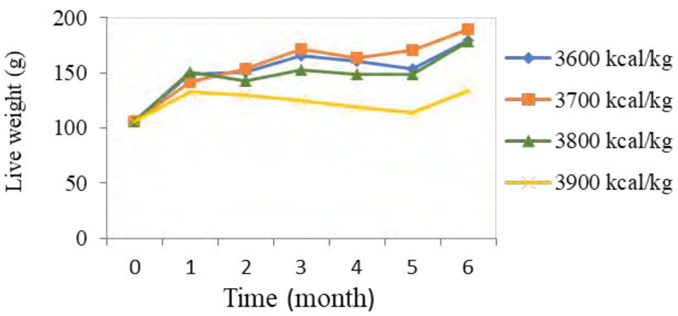

Figure 3: Evolution of the live weight of *L. batesii* depending on the food energy level.

Growth performance of *L. batesii* depending on the food energy level

The effect of energy level on the growth characteristics in juveniles *L. batesii* is summarized in Table 2, Table 3 and Table 4 and illustrated in (Figures 2 and 3). Analysis of variance showed that the energy level significantly ($p<0.05$) influenced the growth characteristics (total, fork and standard lengths, live weight, weight and length gains, average daily gain, specific growth rate and food consumption) studied in *L. batesii* in fattening (Table 2). It appears that all the growth characteristics first increased up to 3700 kcal of ME/kg of DM of food, then significantly ($p<0.05$) decreased with the increasing energy level, except for the consumption index which first decreased (3700 kcal of ME/kg of DM of food), then increased with the increasing energy level. The condition factor K, for its part, varied significantly in the groups receiving feed at 3600 and 3800 kcal of ME/kg of DM and showed a tendency to increase with the increasing food energy level.

Table 2: Growth performance depending on the food energy level in *L. batesii.*

Caracteristics	ME (kcal/kg of DM food)			
	3600	3700	3800	3900
TL (mm)	25.46 ± 0.37^{b,c}	26.5 ± 0.36^{c}	24.62 ± 0.37^{a,b}	23.8 ± 0.37^{a}
FL (mm)	22.65 ± 0.33^{b,c}	23.34 ± 0.32^{c}	21.96 ± 0.33^{a,b}	21.14 ± 0.33^{a}
SL (mm)	20.75 ± 0.29^{b}	20.6 ± 0.28^{b}	19.7 ± 0.29^{c}	19.03 ± 0.29^{c}
LW (g)	178.81 ± 8.02^{a,b}	210.45 ± 7.84^{c}	182 ± 8^{b}	158 ± 8^{a}
WG (g)	73.11 ± 8^{a,b}	104.75 ± 7.84^{c}	76.29 ± 8^{b}	52.3 ± 8^{a}
ADG (g/d)	7.31 ± 0.83^{a}	10.19 ± 0.81^{c}	7.63 ± 0.83^{a}	5.23 ± 0.83^{a}
LG (mm)	3.27 ± 0.37^{b,c}	4.3 ± 0.36^{c}	2.43 ± 0.37^{a,b}	1.62 ± 0.37^{a}
SGR (%)	5.07 ± 0.43^{b}	6.74 ± 0.42^{c}	5.18 ± 0.43^{b}	3.85 ± 0.43^{a}
Factor K (%)	1.07 ± 0.42^{a}	1.13 ± 0.41^{a,b}	1.23 ± 0.42^{b}	1.16 ± 0.42^{a,b}
FC (g)	104.33 ± 0.57^{b}	111.32 ± 0.56^{c}	104.81 ± 0.57^{b}	95.76 ± 0.57^{a}
CI	1.84 ± 0.41^{a,b}	1.2 ± 0.4^{a}	2.16 ± 0.41^{a,b}	3.03 ± 0.41^{b}

Table 3: Length-weight relationship depending on the food energy level in *L. batesii.*

ME (kcal/kg of DM of food)	Parameters of the weight/length relationship				Type de croissance
	Equations	R^2	a	b	
3600	$LW = 0.006TL^{3.15}$	0.92	0.006	3.15	Majorant
	$LW = 0.006SL^{3.39}$	0.68	0.006	3.39	Majorant
	$LW = 0.09FL^{2.43}$	0.86	0.09	2.43	Minorant
3700	$LW = 0.24TL^{2.06}$	0.79	0.24	2.06	Minorant
	$LW = 0.07SL^{2.62}$	0.83	0.07	2.62	Minorant
	$LW = 0.02FL^{2.92}$	0.75	0.02	2.92	Minorant
3800	$LW = 0.01TL^{2.94}$	0.66	0.01	2.94	Minorant
	$LW = 0.02SL^{3}$	0.95	0.02	3	Isométrique
	$LW = 0.05FL^{2.62}$	0.62	0.05	2.62	Minorant
3900	$LW = 0.00TL^{5.15}$	0.89	0.00	5.15	Majorant
	$LW = 0.003SL^{3.72}$	0.84	0.003	3.72	Majorant
	$LW = 0.103FL^{2.39}$	0.74	0.103	2.39	Minorant

Table 4: Biochemical characteristics of the flesh of *L. batesii* depending on the food energy level.

Biochemical characteristics	Metabolizable energy (kcal/kg of DM of food)			
	3600	3700	3800	3900
Ash (% DM)	8.43 ± 0.28^{b}	9 ± 0.33^{c}	8.08 ± 0.26^{a}	8.16 ± 0.23^{a}
OM (% de DM)	91.57 ± 0.29^{a,b}	91.38 ± 0.82^{a}	91.96 ± 0.66^{b}	91.83 ± 0.24^{a,b}
CP (% de DM)	65.45 ± 0.14^{a}	62.96 ± 0.12^{b}	58.54 ± 0.15^{d}	62.44 ± 0.42^{c}
Fat (% de DM)	25 ± 0.15^{a}	25.06 ± 0.09^{b}	23.57 ± 0.07^{c}	22.82 ± 0.18^{d}
Chol T (mg/dL)	29.32 ± 0.76^{a}	22.53 ± 0.86^{c}	22.03 ± 0.79^{c}	25.92 ± 1.05^{b}
TGS (mg/dL)	108.72 ± 1.27^{b}	117.39 ± 1.36^{d}	104.47 ± 1.43^{a}	115.37 ± 1.43^{c}
HDLC (mg/dL)	17.03 ± 1.25^{a}	16.03 ± 1.18^{b}	15.35 ± 1.03^{b}	16.1 ± 1.02^{b}

Monthly evolution of the total length of *L. batesii* depending on the food energy level

The monthly evolution of the total length of *L. batesii* depending on the food energy level is illustrated in Figure 2. It appears that the total length increased throughout the test, whatever the considered energy level, with the exception for carps fed feed at the highest energy levels (3800 and 3900 kcal/ kg of DM of food), which length stagnated for the first five months. Furthermore, the highest values of this characteristic were recorded with the carps receiving food at 3600 kcal/kg during the first five months, then with those receiving food at 3700 kcal/kg, the last month. While the lowest values were obtained with those fed food at 3900 kcal/kg of DM of food, whatever the considered period.

Monthly evolution of the live weight of *L. batesii* depending on the food energy level

The monthly evolution of the live weight of *L. batesii* depending on the food energy level is illustrated in (Figure 3). It appears that this characteristic increased throughout the experiment, with an inflection in the fifth month of rearing, whatever the considered energy level. In addition, the highest values were recorded with fish receiving food at 3700 kcal/kg, except for the first month, when it was the batch at 3800 kcal/kg which dominated. And, the lowest values were noticed among those receiving food at 3900 kcal/kg, whatever the chosen period.

Characteristics of the weight/length relationship depending on the food energy level in L. batesii

The parameters of the weight/length relationship and the type of growth according to the food energy level in *L. batesii* are summarized in (Table 3). It can be deduced from this table that the weight of this African carp is very strongly associated with the lengths (total, standard and fork), regardless of the considered energy level. Furthermore, this relationship follows a power type equation and the determination coefficients R2 are strong in all batches. In addition, the allometry coefficient (b) is greater than 3 in carp fed feed at 3600 and 3900 kcal/kg, thus indicating a growth of the majorant allometry type. The carp fed feed at 3700 and 3800 kcal/kg DM of food presented an allometry coefficient less than 3, thus indicating a growth of the minorant allometry type.

Biochemical characteristics of flesh of *L. batesii* depending on the food energy level

The effect of the food energy level on the biochemical characteristics of the flesh of *L. batesii* is summarized in (Table 4). The analysis of variance showed that all the biochemical characteristics studied were significantly ($p<0.05$) influenced by the food energy level. The concentrations of crude protein, fat and triglycerides varied significantly ($p<0.05$) in all batches. Meanwhile, the ash content varied in the groups receiving feed at 3600 and 3700 kcal of ME/kg of DM of food. As for the concentration of organic matter, it varied significantly ($p<0.05$) in the groups receiving feed at 3700 and 3800 kcal of ME/kg of DM of food. Regarding the total cholesterol content, it varied significantly ($p<0.05$) in the groups receiving feed at 3600 and 3900 kcal of ME/kg of DM of food, while the content of High Density Lipoprotein Cholesterol (HDLC) only varied in the group fed with the food at the lowest energy level. The ash, organic matter and crude protein contents of the flesh increased with the increasing energy level of the food. On the other hand, an opposite trend was recorded with the concentrations of fat, total cholesterol, triglycerides and HDLC. This decrease was significant ($p<0.05$) with carp fed with food at 3800 kcal of ME/kg of DM of food.

Discussion

At the end of this experiment, the significant decrease in the survival rate of juveniles Labeobarbus batesii with the increasing level of food energy corroborates the result reported by [19] with the fingerlings Oreochromis niloticus. Indeed, fed for 28 days, the latter presented a survival rate varying significantly from 100% to 94.73% with the increasing level of lipids (6 to 18%) in the food. The decrease of the survival rate versus the increase of the food energy level would suggest that these carps consume little food at high energy level. This low consumption does not make it possible to cover the nutritional needs of fish and ensure their survival. It appears from these results that the best growth performance was obtained in carps fed with food at 3700 kcal/kg. The significant decrease ($p<0.05$) in length and weight gains, average daily gain, specific growth rate and food consumption with increasing level of metabolizable energy of the food is in agreement with the result noted by [19,20]. These latter authors actually noticed that feed with low energy levels (723 - 2892 kcal of EB/kg) induce an increase in weight gain of 4.75 to 5.71 g [19] and 0.43 to 1.5 g [20], in average daily gain of 0.17 to 0.3 g/d and in specific growth rate of 1.05 to 2.41% [20], respectively in juveniles Oreochromis niloticus in Algeria and in fingerlings Labeo rohita. The same was true for Labeobarbus batesii fry whose growth was optimal when fed food at the lowest energy level (3600 kcal ME/kg) after 180 days of feeding [10]. To this point, [19] states that the quantity of energy contained in the food is a factor which controls the food consumption of fish, and therefore, the growth. The latter is linearly correlated with food availability, which results in the increase of the SGR up to the point of maximum voluntary food consumption. Beyond this point, excess feeding has no effect on growth and instead leads to poor growth and pollution of the rearing water. Some studies have also shown that the reduction in the growth of fishes receiving energy-rich feed results from their inability to digest and assimilate the excess lipids provided [21-25].

In the first years of its life, growth in carp is the metabolic activity that requires the most energy, followed by reproduction, which is an energetically very costly function [26]. In this study, the juveniles *L. batesii* receiving food at the highest energy level presented majorant ($b = 5.15$) growth type, thus suggesting that, at this stage of development, fish favor growth in body mass rather than in length. This result is in agreement with that obtained by [12] who affirm that the spawners of the same species in a natural environment present a majorant allometric growth (b ranging between 2.785 - 3.088). However, it should be noted that, at the first stage of development, carp of the same species rather exhibit growth of a minorant allometry type [10], when fed the same feed (3600 – 3900 kcal of ME/ kg).Regarding the consumption index, the values increased with the increasing level of the food energy. The same observation was made by [27,28] with Clarias jaensis and Dicentrachus labrax larvae, which showed an increase of the CI from 3.86 to 4.36 and from 1.28 to 1.30 respectively, when fed low level energy (2500 to 3300 kcal/kg) feed. On the other hand, (29) found that, after 98 days of feeding, this characteristic decreased from 3.10 to 2.66 with fingerlings Siganus rivulatus, when they were fed very rich (3882 - 4360 kcal/kg) energy feed. The differences in trends and values would be based on the level of energy contained in the food. Indeed, the degree of consumption of nutrients and their use in fish depends on the energy level of the food. Thus, once energy requirements are met, the fish decreases its consumption even if the requirements for other nutrients are not yet met. It is therefore important to determine the optimum level of energy for efficient use and recovery of food, while avoiding waste. During this study in the fattening phase, the increase of the condition factor K with the increasing level of metabolizable energy could mean that, the use of energy-rich feed during brood stock rearing would promote good body condition and their optimal growth. Furthermore, this factor was greater than 1, whatever the considered energy level, thus reflecting, according to [29,30], the good body condition of the fish. This could be explained by the values of the physicochemical characteristics which promote the good growth of *L. batesii* in ponds. The same observation was reported by [12] in fishes of the same species in the natural environment (K between 0.89 and 1.5).

Balanced feed should contain energy levels compatible with protein anabolism, while leading to minimal fat deposition in the carcass [31] or in various tissues and organs. The composition of the flesh is very often used as an indicator of fish quality. After 180 days of rearing, the concentrations obtained in crude protein and water in the carcass of *L. batesii* were lower than those in the flesh of Cyprinus carpio [32-34], contrary to the lipid and ash concentrations, which were rather higher. In addition, the energy level of the food significantly ($p<0.05$) affected all the biochemical characteristics of the flesh. This observation is inconsistent with those reported by [25] in Iran and [35] in Malaysia with juvenile Barbus grypus (29.68 ± 0.19 g) and Tor tambroides (2.09 ± 0.12 g) respectively, of which the protein, water, ash and flesh fats were not significantly influenced by increasing energy level (2672 – 3392 kcal DE/kg and 3950 – 4120 kcal BE/kg, respectively) of the food, after 70 and 84 days of experimentation. The same was true for protein and ash contents in the hybrid Aspikutum (Leuciscus aspius ♀ x Rutilus frisii ♂) in Iran [36] and in Ctenopharyngodon idella in China [23], which were not influenced by the increasing level of gross energy (4156 – 4600 and 2312 – 3392 kcal/kg, respectively). This difference in results could be attributed to the type of energy studied and the initial weight of the juveniles used during the different experiments. Furthermore, the positive correlation between the energy level of the food and the protein concentration of the *L. batesii* carcass suggests that the availability of non-protein energy sources in the feed leads to maximum protein utilization for growth. Indeed, the inclusion of non-protein energy preserves dietary proteins resulting from catabolism for the purposes of optimizing growth in fish [37]. With lower values (14.52 – 5.45% MF; 15.5 – 17.4% MF and 128 – 137 g/kg, respectively) than those obtained in this study [20,37,38], all from India, reported a similar trend in Labeo rohita and Puntius gonionotus, respectively. In this present work, the fat and water concentrations significantly decreased with the increasing energy level of the food. This could be explained by the negative correlation established between the energy level of the food and the concentrations of fat on one hand and water on the other. This observation corroborates those of [36] in the hybrid Aspikutum in Iran and [23] in Ctenopharyngodon idella in China, who revealed a decrease in fat (from 7.5 to 6.45% MF) and water (from 768.4 to 734.8 g/kg) contents with increasing level of gross energy (4156 – 4600 and 2312 – 3392 kcal/kg) after 60 and 70 days of experimentation.

The transport of lipids (in the form of cholesterol) in the body is ensured by lipoproteins, in particular HDLC (High Density Lipoprotein Cholesterol) and LDLC (Low Density Lipoprotein Cholesterol). HDLC carries cholesterol to the liver, while LDLC carries it to the arteries, where it will form plaques that prevent blood flow [39]. In the present study, the highest concentrations of total cholesterol, triglyceride and HDLC observed in carps fed food at the lowest energy level suggest that this food induce more active endogenous lipid storage. This result is not in agreement with those reported by certain authors. Indeed, [40] recorded in the African catfish Clarias gariepinus in Nigeria after 42 days of feeding, plasma cholesterol contents higher than those obtained in this work, which increased significantly from 220 ± 2.10 to 230 ± 6.78 mg/dL and from 229 ± 6.77 to 266 ± 7.29 mg/dL respectively, with the increasing rate (from 5 to 10%) of peanut oil incorporation (2874 – 2834.5 kcal of EB/kg) and coconut oil (2860 – 2825 kcal of EB/kg) of the food. Similarly, [23,41] reported in juvenile C. idella and Nibea coibor in China, triglyceride concentrations (from 0.94 to 1.67 mmol/L and from 5.61 ± 0.3 to 8.50 ± 0, 76 mmol/L, respectively) and total cholesterol (from 1.56 to 2.67 mmol/L and from 2.02 ± 0.36 to 3.03 ± 0.33 mmol/L, respectively) much lower than those obtained and correlated with the increasing energy level (2312 - 3392 kcal of EB/kg and 2533 - 3083 kcal of ED/kg) of the food, after 70 and 49 days of experimentation. The difference in trend observed between the different works would be due to the type of oil used in the preparation of these feed. The lipids that could not be stored either in the liver or in the organs, form perivisceral fat. Thus, males and females receiving the energy-rich feed presented the significantly higher fat index values ($p<0.05$). This situation was also noted by [27] with C. jaensis whose fat index was higher in those fed feed with a high energy level (3200 and 3300 kcal ME/kg) , although the values are low (0.012 ± 0.006 for ♂ and 0.008 ± 0.004 for ♀) to those obtained in this present work.

Conclusion

At the end of this study on the effect of the level of metabolizable energy on survival, growth performance and biochemical characteristics in Labeobarbus batesii in captivity, it appears that the energy level significantly influenced both the rate of survival as all the growth and biochemical characteristics of the flesh. Furthermore, the survival rate was higher with the treatment at 3600 kcal ME/kg, while the highest growth characteristics were recorded with the treatment at 3700 kcal/kg, except the index of consumption which was low. Regarding the biochemical characteristics of the flesh, the contents of CP, Chol T and HDLC were higher with the treatment at 3600 kcal/kg while the contents of ash, fats and TGS were higher with the treatment at 3700 kcal/kg. The metabolizable energy level of 3700 kcal/kg is therefore recommended for food formulation for the African carp Labeobarbus batesii in fattening. However, for better control of the nutritional needs of this species, it would be necessary to continue this work up to the reproductive stage by evaluating the effect of the energy level of the food on the reproductive performance, but also on the growth performance of the new generation.

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