

Length-weight relationships and prediction equations of body composition of farm raised *Astyanax aff. fasciatus* (Actinopterygii: Characiformes: Characidae)

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ABSTRACT. This study ascertains the length-weight relationship and predicts body composition equations in cultivated *Astyanax aff. fasciatus*. A total of 300 fish were distributed in five groups according to body weight: 1.19 ± 0.18 , 3.7 ± 0.70 , 7.55 ± 0.97 , 12.28 ± 2.32 and 22.16 ± 2.64 g. The length-weight relationship was elaborated using linear ($y_i = \beta_0 + \beta_1 x_i$) or second-order ($y_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2$) regression analysis. The value of the b slope in the length-weight relationship was 3.6971 and the intercept was 0.0031. The prediction equations obtained for body moisture, crude protein, crude lipid and ash were, $y = 71.680 - 0.404BW$, $y = 17.140 - 0.095BW$, $y = 8.432 + 0.364BW$ and $y = 3.720 - 0.032BW$, respectively, where BW is the body weight of fish (g). The use of prediction equations to describe body composition as a tool to support fish production and commercialization is suggested.

KEY WORDS. Aquaculture; fish; growth; mathematical modeling; regression analysis.

Systematic studies have shown that *Astyanax* Eigenmann, 1917 is represented by distinct species with controversial taxonomy (REIS *et al.* 2003) and chromosomal plasticity (MEDRADO *et al.* 2008). The genus comprises 92 valid species (BERTACO & LUCENA 2006, MELO & BUCKUP 2006).

Mathematical models of fish growth offer an objective and practical way to describe growth and to estimate weight between sampling intervals. They may also offer accurate estimations of standing biomass and the amount of food needed for optimal fish production. Length and weight are standard data used in fish programs (CHERIF *et al.* 2008) to estimate growth rates (KOHLER *et al.* 1995). Length-weight relationships allow conversion of growth-in-length into growth-in-weight in stock assessment models (MORATO *et al.* 2001), estimation of biomass from length frequency distributions, estimation of fish condition (PETRAKIS & STERGIU 1995), assessment of morphological characteristics of fish populations (STERGIU & MOUTOPOLOUS 2001) and maturity of individuals (FAFIOYE & OLUAJO 2005). The length-weight relationships in fish are important tools in aquaculture management.

Growth, defined as a change in scale, is one of the most significant parameters in aquaculture. It can be measured as a function of size or tissue composition. Nutrition, genetics and health studies have recently started to focus more on fish body composition (BLANCHET *et al.* 2005, TOBIN *et al.* 2006), and given the increasing interest in fish quality and its nutritional value for

human consumption (AZAM *et al.* 2004), the subject has been reviewed by various authors (DUMAS *et al.* 2010, MOZAFFARIAN & RIMM 2006, KAMAL *et al.* 2007). Despite the usefulness of length-weight relationship and body composition, and the great economic importance of *Astyanax aff. fasciatus* to aquaculture in Brazil, this kind of information is lacking for cultivated fish. This work aims to determine length-weight relationships and to elaborate prediction equations of body composition for cultivated *Astyanax aff. fasciatus* using regression analysis.

MATERIAL AND METHODS

The study was performed in the application unit of the Aquaculture Laboratory, Universidade Estadual de Ponta Grossa, Paraná, Brazil. Fish were obtained from a local fish farm (Piscicultura Águas Claras, Castro, Paraná, Brazil; $24^{\circ}42'32''S$ and $50^{\circ}02'37''W$). A total of 300 fish were collected randomly between October 2011 and March 2012. Specimens are deposited in the Núcleo de Pesquisa em Limnologia, Ictiologia e Aquicultura/Coleção Ictiológica at the Universidade Estadual de Maringá (NUP 11864), Maringá, Paraná, Brazil. Fish samples were obtained from two earth ponds, 300 m² each. They were captured with surface and bottle trawl net (mesh size = 1 cm), and were kept without food for 24 h before the beginning of the experiment. The latter was conducted in a 500-L indoor fiberglass tank aerated to main-

tain dissolved oxygen of > 5 and < 6 mg/L. Fish were not fed artificial diets and given only natural food. Specimens were euthanized by overdose of benzocaine (3 g/10-L), after which their total length and body weight (0.01 g) were measured individually (0.1 cm) and classified into five weight classes (1.19 ± 0.18 , 3.7 ± 0.70 , 7.55 ± 0.97 , 12.28 ± 2.32 and 22.16 ± 2.64 g), each containing three groups. Each treatment (weight class) consisted of 60 fish, which were divided into groups of 20 for the proximate composition analysis. Fish were minced and stored in a freezer (-80°C) for later analysis of body composition.

The proximate composition analyses of fish samples were performed following AOAC (1990) procedures. Water content was determined by placing fish in a pre-weighed aluminum foil tray for drying in an electric oven at 55°C until constant weight and oven drying at 105°C for 24 hours; crude protein (nitrogen $\times 6.25$) was determined by the Kjeldahl method, after acid hydrolysis; lipid was extracted by petroleum ether in a Soxhlet apparatus followed by determination of lipid gravimetrically, and ash was determined by combustion at 550°C, in a muffle furnace, until constant weight was reached.

Data on total length (L) in mm and body weight in g were recorded for each fish. The parameters a and b of the length to weight relationship were estimated using the logarithmic transformation of the equation: $W = aL^b$, where W is body weight, g and L length, cm. The values of constant a and b were estimated from the log transformed values of length and weight ($\log W = \log a + \log L$) via the least square linear regression. The average value of b was tested to verify if it was significantly different from 3 using t -test at the 0.05 significance level. All statistical analyses were performed using the statistical package SPSS 14.0. The data on body composition were analyzed by one-way analysis of variance (ANOVA). Percentage data were transformed to arcsine values before analysis (ZAR 1996). The significance level was 0.05. Prediction equations of the body composition of *Astyanax aff. fasciatus* were elaborated using linear ($y_i = \beta_0 + \beta_1 x_i$) or second-order ($y_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2$) polynomial regression analysis (ZEILTON et al. 1976).

RESULTS

The length-weight relationship was established through the equation $W = 0.0031 \times L^{3.6971}$ ($R^2 = 0.9796$) (Fig. 1). Mean percentages of moisture, crude protein, crude lipid and ash contents according to the body weight of *Astyanax aff. fasciatus* are presented in Table I.

All linear regressions resulted highly significant, with the coefficient of determination (r^2) ranging from 0.836 to 0.937 ($p < 0.05$). The relationship between body moisture, crude protein and crude lipid and body weight was best expressed using linear regression analysis (Table II), and body composition can be expressed using the expressions: Moisture = $71.680 - 0.404BW$; Crude protein = $17.140 - 0.095BW$; Crude lipid = $8.432 + 0.364BW$; Ash = $3.720 - 0.032BW$; where: BW is the body weight of fish (g).

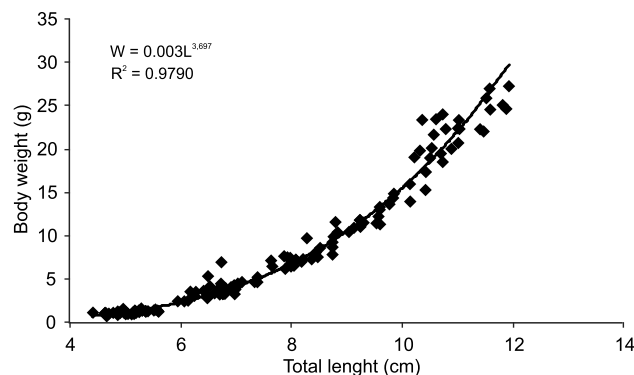


Figure 1. Length-weight relationship of market size cultivated female *Astyanax aff. fasciatus*.

Table I. Whole-body composition (mean \pm SD) of *Astyanax aff. fasciatus* according to body weight (% wet weight basis).

Body weight (g)	Body composition (%)			
	Moisture	Crude protein	Crude lipid	Ash
1.190	72.05 \pm 0.22	17.63 \pm 0.85	7.16 \pm 0.19	3.91 \pm 0.04
3.780	69.82 \pm 0.33	16.74 \pm 0.79	10.79 \pm 0.04	3.48 \pm 0.08
7.558	68.5 \pm 0.21	16.36 \pm 0.41	11.42 \pm 0.18	3.42 \pm 0.28
12.288	65.43 \pm 0.37	16.86 \pm 0.62	13.51 \pm 0.27	3.19 \pm 0.03
22.160	63.25 \pm 13	17.50 \pm 0.88	15.12 \pm 0.19	3.08 \pm 0.02

Values are the mean \pm SD of triplicate groups.

Table II. Statistical details showing number of fish studied (n), intercept (β_0), slope (β_1), p-value (p) and correlation coefficient of cultivated *Astyanax aff. fasciatus*.

Item	Body composition (%)			
	Moisture	Crude protein	Crude lipid	Ash
n	60	60	60	60
β_0	71.680	17.140	8.432	3.720
β_1	-0.404	-0.095	0.364	-0.032
P	<0.01	<0.01	<0.01	<0.01
r^2	0.930	0.836	0.859	0.861

DISCUSSION

Fish growth models follow the "cube law" and Fulton's condition factor or isometric factor ($k = W/L^3$), where K = condition factor, M = body mass, L = body length, and the weight-length exponent $b = 3$ (GULLAND 1983), which assumes that body shape maintains a constant proportion to length (WEATHERLEY & GILL 1987). In the present study, b (3.136) value significantly higher from 3 and this implies that the "cube law" cannot be applied to this species.

In the present work, the effect of body weight ($p < 0.01$) on whole body moisture, crude protein, crude lipid and ash was linear. As observed by many authors, when fish grows in size, it deposits relatively more fat than other tissues (SALAM & DAVIES 1994, SALAM *et al.* 2001). The distribution of body components among the various organs and tissues of the body may also show considerable differences (WEATHERLY & GILL 1987). However, whole body composition varies in a similar manner among species as fish size increases (LUPATSCHE *et al.* 2001, DUMAS *et al.* 2010). The live weight of fish, as a rule, consists of about 70 to 80% water, 20 to 30% protein and 2 to 12% lipid (LOVE 1980).

Body composition of fish is affected by several factors, including fish species (ALI *et al.* 2005), environmental variables (ALI *et al.* 2001), dietary factors and body size (EBRAHIMI & OURAJI 2012). Information about fats, protein and mineral composition of fish in relation to size is important for consumers and facilitates the selection of species having the highest protein content at specific size (ALI *et al.* 2005). This is important because fish is one of the main sources of protein for humans in developing countries (LOUKA *et al.* 2004).

Percentage of moisture is a good indicator of the relative contents of total body energy, proteins and lipids (ALI *et al.* 2005). The lower the percentage of moisture, the greater the percentage of lipids and higher the energy density of fish (DEMPSON *et al.* 2004). In the present work, a highly significant linear increase was found between body weight and fat content (based on wet and dry weight), but moisture and crude protein content linearly decreased with an increase in body weight. This result is in agreement with the findings reported by SALAM *et al.* (2001), who observed that the fat content of Nile tilapia increases with fish size.

Condition factor is considered one of the important factors influencing body composition in fish (SALAM & DAVIES 1994). But the condition factor is not always proportional to the cube of its length (WEATHERLEY & GILL 1987) and can pose problems in the interpretation of obtained values. YOUSAF *et al.* (2011) found no significant difference between the body components of male and female *Wallago attu* Wallago attu Bloch & Schneider, 1801. In Brazil both sexes of *Astyanax aff. fasciatus* are commercialized together and the market size of fish is related only to weight.

The importance of meat quality in animal production with respect to the requirements of specific markets was previously addressed by McMEEKAN (1941). He also commented on the technical difficulties, time and high cost associated with chemical analysis, emphasized the need to develop mathematical equations, and proposed linear regression equations to predict fat, muscle and bones in pigs. His results are in agreement with MEMIS *et al.* (2006), who concluded that body elements can be estimated from fish weight using the predictive regression models developed in this work with a reasonable amount of accuracy.

In conclusion, the body composition of *Astyanax aff. fasciatus* varies according to body weight and body weight can be estimated by length-weight relationships. Body composi-

tion can be estimated by prediction equations of linear regression analysis.

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