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NUTRITIONAL COMPOSITION AND LIPID CONTENT OF SKIN AND MUSCLE OF WILD GIANT MOTTLE EELS *ANGUILLA MARMORATA* IN THUA THIEN HUE, VIETNAM

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Abstract: In Vietnam, the giant mottle eel *Anguilla marmorata* is the most widely distributed species and being exploited for seed in aquaculture as well as for human consumption. This study aims to investigate the basic nutritional components of the fish. The eels were collected from six locations of Thua Thien Hue province, with weights from 5 to 3200 g. In addition, the content of lipid in skin and tissue was also examined. The results show that eel flesh has a relatively high nutritional value. The water, protein, lipid, and total sugar content of the fish meat is 60.4 ± 0.94%, 19.54 ± 4.31%, 18.2 ± 1.02%, and 1.34 ± 0.34 (mg/g), respectively. The nutritional components of the eel have a good correlation with the weight according to the equation: $Y = a \times \ln(W) + b$ (where W is the weight of eels; Y is the content of nutritional components; a is the correlation coefficient b is a constant) with $r > 0.9$. The lipid content of the fish skin is higher than that of muscle and meat.

Keywords: eel, protein, lipid, water, total sugar, weight

1 Introduction

Anguilla marmorata is the second largest of the 16 species and three sub-species of eels of *Anguilla* [6, 16–18], with the most extensive geographical distribution in two different oceans (tropical and subtropical central Pacific and the Indian Ocean) [13]. The habitat covers the east coast of Africa across the Indian Ocean [6], including India and Sri Lanka, the Indo-Pacific region (Indonesia, Philippines, and Papua New Guinea), and the island chains in the central South Pacific (the Marquesas Islands and French Polynesia). Vertically, this species is distributed in South-Western Japan, Taiwan, South-east China, in the south (Vietnam and Malaysia), and especially the Southern Cape in South Africa [19].

In Vietnam, *Anguilla marmorata* is distributed widely in coastal areas, estuaries, lagoons, lakes, rivers, and freshwater streams from Ha Tinh to Vung Tau, the Highlands, and Phu Quoc Island, most of which is from Thua Thien Hue to Khanh Hoa [1]. Giant mottle eels are a valuable and preferred species for human consumption because of their high nutritional value, good flesh quality, and export value, and thus they are considered as a species with high economic importance [3]. Huss [9] reported that the nutrition in the fish meat comprises water (26–96%),

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lipid (0.2–25%), protein (6–28%), ash (0.4–1.5%), and carbohydrate (<0.5%). The nutritional composition of the fish fluctuates, depending on internal and external factors [21], such as species, age, gender, stage of development, diet, and habitat [6, 21]. Similarly, the nutritional content of wild eels is expected to vary with the growth stages by the differences in natural foods [10, 5]. The body composition is, therefore, a true reflection of eating habits and the type of food available [21]. In this study, the variation of nutritional components, namely protein, lipid, total sugars, and water content, in the meat of the giant mottle eels naturally distributed in Thua Thien Hue is studied. Besides, this study also looks at the distribution of lipid in different parts of the eels' flesh. The results will provide the basis for selecting the commercial quantity and food processing from the eels.

2 Materials and methods

2.1 Sampling

One hundred and twenty-seven giant mottle eels (*Anguilla marmorata*) sized 17–1080 mm and weighted 10–3200 g were collected from six locations in Thua Thien Hue (Fig. 1) in July 2018 and August 2019 (Table 1). Eel's meat was divided into two parts: skin and tissue (Fig. 2). In particular, the meat (skin and muscle) was used to analyze the protein, lipid, total sugar, and water. The lipid content was analyzed separately for skin and muscle to see their distribution in the wild eel's meat. The samples were divided into four groups according to the weight of fish: <100 g (glass eels), 100–500 g (elver eels), 500–1000 g (golden eels), and >1000 g (silver eels).

Table 1. Sample characterization

No.	Locations	Number of samples	Ratio (%)	Total weight (g)	Total length (mm)
1	Thao Long Dam	26	20.5	52.3–3200.0 511.5 ± 776.69	303–1080 513.00 ± 186.13
2	Truoi Dam	23	18.1	24.5–269.5 104,7 ± 103.64	215–527 333.8 ± 126.39
3	Nam Dong district	26	20.5	9.9–511.1 107.2 ± 117.54	170–620 337.1 ± 110.74
4	Phong Dien district	28	22.0	12.9–493.9 184.3 ± 140.52	205–610 413.2 ± 116.1
5	Bu Lu river and Lang Co town	24	19.0	5.9–89.0 27.2 ± 18.91	150–362 236.4 ± 53.75
Total		127	100.0	9.9–3200 202.5 ± 444.40	17–1080 365.66 ± 163.75

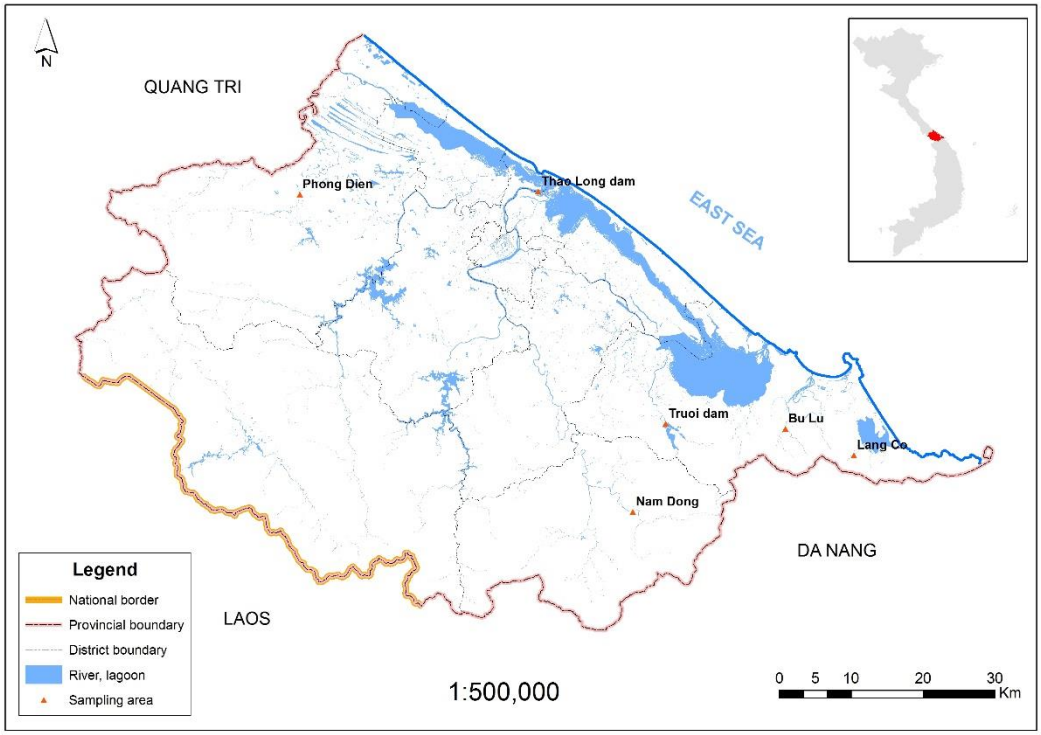

Fig. 1. Sample collecting map

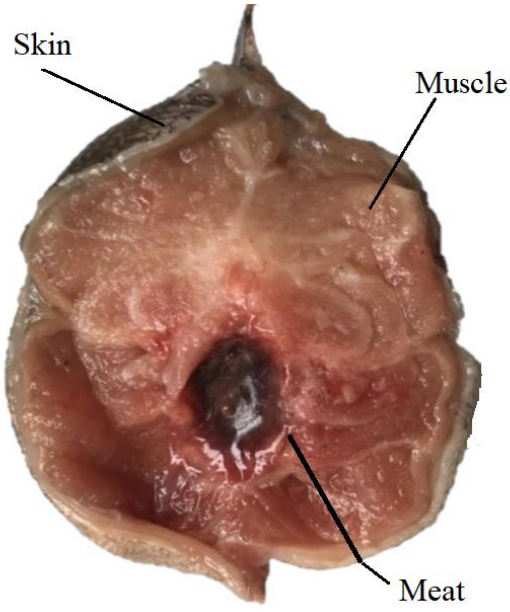

Fig. 2. Eel pattern

2.2 Water content

The water content was determined before and after drying in three replicates by drying 1 g of sample in an oven at 105 °C until constant weight (after the first three times more weight). The water content is calculated according to formula (1) [4]

$$\text{Water content (\%)} = \frac{m - m_0}{m_0} \times 100 \quad (1)$$

where m and m_0 are the weight of the sample after and before drying.

2.3 Lipid content

Two grams (W_0) of eel meat/skin/muscle was wrapped in one layer of cotton and one sheet of filter paper on the outside. The sample was extracted with n-hexane in Soxhlet apparatus for 6 hours. The extract is then dried in an oven at 105 °C to remove the solvent. The lipid content was calculated according to formula (2) [4]

$$\text{Lipid (\%)} = \frac{W}{W_0} \times 100 \quad (2)$$

where W and W_0 are the weight of the fat and the sample, respectively.

2.4 Protein content

The protein content of the sample was determined with the Bradford method [11]. The basic principle of this method is based on the change of the maximum absorption wavelength of Coomassie dye Brilliant Blue when creating complexes with proteins. In an acidic solution without protein, the red dye has a maximum absorption wavelength of 465 nm. When combined with the protein, the color turns blue and maximizes absorption at 595 nm. The absorption at 596 nm is directly related to protein concentration.

To determine the protein in a sample, first, a calibration curve with a known standard protein solution was constructed. After adding the protein solution to the dye, the color appeared after two minutes and lasted up to one hour. The absorbance of the solution was measured on a spectrophotometer (ODX). The absorbance is proportional to the amount of protein in the sample. A control with HCl (ODO) was carried out. The value ODOD = ODX – ODO was calculated. The amount of protein in a sample was determined according to the calibration curve from the ØOD value on the vertical axis, thus deducing the corresponding protein concentration on the horizontal axis. From the standard equation and the optical density of the sample, the protein content of the sample is given by formula (3)

$$\text{Protein content (mg/g)} = \frac{X}{1000 \times m} \quad (3)$$

where X is the density/concentration of the sample; m is the sample size for analysis.

2.5 Total sugar content

Two grams of eel flesh was used to analyze the total sugar content, following the color reaction between sugar and dinitrosalicylic acid (DNS), according to the method described by AOAC [4]. The color intensity of the reaction mixture is directly proportional to the strength of the dinitrosalicylic acid-reducing sugar, which expresses the total sugar of the sample. Eel flesh after weighing was added to 50 mL of distilled water in a beaker, which was kept in a water bath at 74 °C for 2 hours. Next, 1 mL of 0.5% HCl solution was added to the beaker and kept for another 15 minutes, and the beaker was cooled quickly under running water. The solution was neutralized with NaOH until the solution turned pink (with phenolphthalein). Ten millilitres of the neutralized solution was concentrated; then, 2 mL of distilled water was added to make a standard solution. The absorbance of the resulting complex solution was measured at 530 nm . From the calibration curve $y = 12.20 \times x - 0.818$ (where x is the absorbance, and y is the content of glucose), the standard glucose content was calculated according to formula (4)

$$C = \frac{V_1 \times x}{V_2 \times m} \quad (4)$$

The total sugar content in the sample was then calculated according to formula (5)

$$X\ (\text{mg/g}) = \frac{m_1 \times V_1 \times n}{V_2 \times m} \quad (5)$$

where m_1 is the concentration of sugar in the standard solution (mg/mL); m is the weight of the sample (g); n is the dilution factor; V_1 is the initial standard volume; V_2 is the volume of the reaction.

The correlation between the nutrient composition and the weight of eel flesh was determined by using multivariate regression analysis in the SPSS 22.0 software.

3 Results and discussion

3.1 Nutrient content in meat of *Anguilla marmorata*

Table 2 indicates that water is the highest proportion in the flesh of fresh eels, accounting for 60.4 ± 0.94%, followed by protein (19.54%), lipid (18.2%), and sugar (1.34%). The water content of the present study is lower than that of *A. marmorata* but higher than that of *A. bicolor bicolor* (57.17 ± 0.98%) [12].

Table 2. Average value of nutrient content of *Anguilla marmorata*

Nutritional ingredients	***A. marmorata***	***A. marmorata*** [12]	***A. bicolor bicolor*** [12]	***Salmo salar*** [8]
Water (%)	60.4 ± 0.94	65.51 ± 0.42	57.17 ± 0.98	61.07 ± 0.03
Lipid (%)	18.2 ± 1.02	21.35 ± 2.48	13.26 ± 0.61	17.23 ± 0.73
Protein (%)	19.54 ± 4.31	17.17 ± 0.71	16.78 ± 2.8	20.28 ± 0.06
Total sugar (mg/g)	1.34 ± 0.34	–	–	–

The lipid content ranges from 17.18 to 19.22%, which is lower than that of *A. marmorata* (21.35 ± 2.48%) [12] and *A. bicolor* (28.29%) [20]. The lipid content of *A. marmorata* is higher than that of *A. japonica* (10.85–19.44%) [15] and *A. bicolor bicolor* (13.26 ± 0.61%) [12].

Protein plays a vital role in the development of organisms. In this study, the protein content of wild eel flesh is 19.54 ± 4.31%, higher than that of *A. marmorata* (17.17 ± 0.71%) and *A. bicolor bicolor* (16.78 ± 2.8%) [12]. The high protein content of eel flesh is related to the animal-based diet, with the preferred food being the crustaceans [10].

The total sugar content of eel flesh is 1.34 ± 0.34 mg/g (Table 2).

The nutritional contents in the flesh of giant mottle eels distributed in Thua Thien Hue are comparable to that of salmon with the water, lipid, and protein content of 61.07 ± 0.03, 17.23 ± 0.73, and 20.28 ± 0.06%, respectively [8].

It is difficult to distinguish between young eels and underdeveloped eels in different life stages. In particular, small eels and underdeveloped eels begin to grow in the same phase (glass eels) and have the same weight [7]. Table 3 shows the fluctuation in the nutritional content in eel flesh of different size groups. Accordingly, the water content of eel flesh varies from 72.8 to 55.8% and decreases gradually with increasing fish bodyweight. Meanwhile, the value of protein, lipid, and sugar content increases. These results are consistent with those reported by Huss [9] and show a similar trend with those of European eels (*A. anguilla*) weighted 9–420 g [7].

Table 3. Fluctuation of nutritional content in eel flesh by weight (%)

Weight	**<100 g**	**100–500 g**	**500–1000 g**	**>1000 g**
Water	72.8 ± 1.56	65.0 ± 1.87	60.3 ± 2.74	55.8 ± 1.18
Lipid	16.1 ± 0.50	18.7 ± 0.60	21.5 ± 1.15	26.7 ± 1.66
Protein	13.98 ± 2.22	19.80 ± 1.90	22.13 ± 0.79	25.30 ± 1.21
Total sugar	1.28 ± 0.23	1.32 ± 0.33	1.58 ±0.09	2.09 ± 0.19

Table 4. Correlation between nutritional components and weight in the flesh of *A. marmorata*

Nutritional ingredients	Correlation equation	R^2	R
Water	$Y = -3.806 \times \ln(W) + 84.553$	0.88	0.94
Protein	$Y = 2.6607 \times \ln(W) + 5.2529$	0.95	0.97
Lipid	$Y = 1.8018 \times \ln(W) + 1.6694$	0.82	0.91
Sugar	$Y = 0.0798 \times \ln(W) + 1.0129$	0.92	0.96

Note: Y is the nutritional value, and W is the weight of the eel

According to the value of the nutritional ingredients in *A. marmorata*, a good positive correlation between the nutrition components (protein, lipid, and sugar) and the eel body weight is observed with $R > 0.9$ [2] (Table 4). This means that within the permitted limits, the content of nutrients increases with body weight. In contrast, water content shows a negative correlation. Premature eels contain less water than the young. These results are consistent with those reported by Degani et al. [7] when analyzing the relationship between the nutritional composition and the weight of European eels *A. anguilla* weighted 9–420 g.

Besides, from the correlation equations, we can see that significant changes of nutritional components (the decrease of water and increase in other ingredients) are observed when the eels are in the small stage weight >400 g. In the weight range of 400–1000 g, the nutritional components of giant mottle eels *A. marmorata* tend to decrease; when the fish weights are greater than 1000 g, the variations reach a steady-state (Table 3 and Table 4).

3.2 Distribution of total lipid content in eel meat

The flesh of all wild giant mottle eels *A. marmorata* in Thua Thien Hue, weighted 7–3200 g, has a higher content of lipid in the skin (28.56 ± 2.15%) than in the muscle (18.10 ± 1.57%) and meat (23.33 ± 1.89%). The lipid content increases with the bodyweight groups from 13.5 ± 0.29% (<100 g) to 26.2 ± 0.89% (>1000 g) in muscles, 21.0 ± 0.79% to 32.4 ± 1.32% in skin, and 16.1 ± 0.50 to 26.7 ± 1.66% in meat (Table 5). On the other hand, a small increase in the lipid content in muscle is observed for the eels lighter than 500 g (from 13.5 to 15.1%). When the eels reach weight in the range of 500–1000 g, there is a sudden increase in lipid content in the muscle (15.1 ± 0.92% to 20.2 ± 2.02%). It is possibly due to the accumulation of fat during the migration and reproduction of eels in the wild [14]. The differentiation of the fat content is also due to different parts of the fish's body and different seasons throughout the year [14, 21]. In this study, the lipid content in flesh is the sum of the lipid content in the skin and muscle of the eels.

Table 5. Total lipid content in *Anguilla marmorata* eel flesh by weight

No.	Weight (g)	Lipid in muscles (%)	Lipid in the skin (%)	Lipid in meat (%)
1	<100	13.5 ± 0.29^{a}	21.0 ± 0.79^{c}	16.1 ± 0.50^{b}
2	100–500	15.1 ± 0.92^{a}	26.1 ± 1.21^{c}	18.7 ± 0.60^{b}
3	500–1000	20.2 ± 2.02^{a}	26.3 ± 2.14^{b}	21.5 ± 1.15^{b}
4	>1000	26.2 ± 0.89^{a}	32.4 ± 1.32^{b}	26.7 ± 1.66^{a}
5	Average	18.10 ± 1.57	28.56 ± 2.15	23.33 ± 1.89

Note: In the same row, letters a, b, and c show a statistically significant difference with $p < 0.05$

4 Conclusion

Wild *A. marmorata* has a high nutritional value, which is dependent on their body weight. The nutritional components increase with weight, except the water content. They have a close correlation with the body weight and reach a stable value when the weight of the fish is greater than 400 g. In the flesh of the giant mottle eels *A. marmorata*, lipid accounts for a greater proportion than other nutritional components and is mostly distributed in the skin.

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