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The edible apple snail [*Pomacea dolioides* (Reeve, 1856)]; meat yield and sensorial evaluation

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Abstract

The present work investigated the meat yield of the gastropod *Pomacea dolioides* (Reeve, 1856), and sensorially evaluated its main organoleptic properties. The average meat yield of *P. dolioides* was 11.9 ± 3.4%, of which 10.9 ± 3.3% was for young females, 12.5 ± 2.8% for adult females, 12.1 ± 4.2% for young males, and 12.4 ± 2.2% for adult males. No significant difference was found in meat yield between sex, but a significant difference was detected in size. A significant difference was also found in the sensory analysis, as the treatment in which the gastropods were fed with grass and ration obtained the best evaluation, reaching over 70% approval for all meat attributes. Although the meat yield of *P. dolioides* was low, its general quality was satisfactorily accepted by the panellists. The meat of this commercially unexploited gastropod is a source of low-cost protein for people with dietary food limitations and underprivileged populations of the Amazon region, and might constitute an alternative and supplementary source of income for local animal producers.

Introduction

Humans have been consuming gastropods since the Palaeolithic era, and records of gastropod shells in caves and shell mounds in North Africa dated back to the prehistoric times (Lloveras *et al.,* 2011). Tools for drilling and extracting soft parts of shells have been identified, and dated back to the last interglacial period, in a cave located in north-eastern Libya (Hill *et al.,* 2015). Moreover, former inhabitants of Tikal (Guatemala), one of the most important populations and cultural centres of the Mayan civilisation, consumed *Pomacea flagellata* (Soy, 1827) as a dietary supplement (Moholy-Nagy, 1978).

Gastropods are excellent sources of protein and minerals, and they have low lipid content. Hence, they are recommended for those suffering from diabetes and hypertension, and those that adopt a healthy diet (Engmann *et al.,* 2013). Due to this nutritional potential, some gastropod species have been consumed in different parts of the world such as Bangladesh, *i.e., Pila globosa* (Swainson, 1822), *Bellamya bengalensis* (Lamark, 1822), and *Melania tuberculata* (Of Müller, 1774) (Baby *et al.,* 2010). *Helix pomatia* (Linnaeus, 1758) has been reportedly consumed in Latvia (Ikauniece *et al.,* 2013), and *Archachatina marginata* (Swainson, 1821) and *Limicolaria aurora* (Jay, 1839) are consumed in some African countries, especially Nigeria (Udoh *et al.,* 1995; Omolara and Olaleye, 2010). Within the genus *Pomacea* (Perry, 1810), *P. canaliculata* (Lamarck, 1822) is consumed in Ghana, while *P. patula catemacensis* (Baker, 1922) and *P. flagellata* are reportedly consumed in Mexico (García, 2003; Afetsu and Kumah, 2016).

The meat yield of *P. canaliculata* after cooking is 20% (Serra, 1997), while in *P. lineata*, the yield ranges between 21.3 and 23.9% of its total weight, which is viable for commercial exploitation since they are slaughtered after four months of cultivation, thus lowering production costs (Barboza and Romanelli, 2005). Size, weight, and chemical composition of the edible portion are vital to evaluate the supply and verify the status and relationship between diet and food consumption (Pessôa *et al.,* 2015).

The process used to prepare this meat for human consumption includes shelling, washing, and boiling since consuming raw or poorly cooked meat may cause infection by *Angiostrongylus cantonensis* (Chen, 1935), a worm originally from Asia that causes angiostrongyliasis through *P. canaliculata* (Tsai *et al.,* 2003) and other gastropod species. Consumers nowadays are becoming more aware, and demand for food with minimal additives, processing, and alterations in sensory quality (Kilcast and Subramaniam, 2000). Sensory scales enable a direct

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comparison between one or more samples in terms of acceptability, and these scales are highly beneficial as pre-market evaluation (Bergara-Almeida and da Silva, 2002).

The processed and canned meat of *Achatina fulica* (Bowdich, 1822) and *P. lineata* have been evaluated sensorially, and considered feasible for consumption, reaching an acceptance of 60% in both cases (Barboza *et al.,* 2006). In a study in which a diet of potato leaves (*Ipomoea batatas* (L.) Lam), and a diet with formulated concentrate were added to the feed of *A. marginata*, the sensory properties did not differ significantly in terms of colour, flavour, and texture, while the taste of the meat and the general acceptability of the gastropods fed with natural potato leaves were higher (Adeola *et al.,* 2010).

Gastropod meat has been widely studied as an alternative source of protein for human consumption, and its acceptability is influenced by culture, nature, and environment (Afetsu and Kumah, 2016). Regarding *P. dolioides* (Reeve, 1856), studies have been conducted on its cultivation (Pires-Júnior *et al.,* 2019), effect of the dry season on the populations, species reproductive biology including the occurrence of "imposex", fecundity, and selection of substrate for oviposition, histology, and histochemistry of the male reproductive tract (Sant'Anna and Hattory, 2017). However, no studies have been conducted on the edible portion of *P. dolioides*, an abundant gastropod in the Amazon region, that can be used as a food source for underprivileged populations. Therefore, the aim of the present work was to assess the meat yield of *P. dolioides* in relation to size and sex, and conduct a sensory evaluation of the meat organoleptic properties of this gastropod fed with different diets.

Materials and methods

Field sampling

Samples of *P. dolioides* were collected from a neighbourhood in the municipality of Itacoatiara, Amazonas, Brazil (03°08'19.9"S; 058°27'32.5"W), between June and August of 2017, at the end of the flood season when *P. dolioides* are abundant in the floodplains. Samples were collected with the permission of the Chico Mendes Institute for Biodiversity Conservation (ICMBio, SISBIO #61438-1). Samples were collected manually or using a hand net (40 cm diameter, 2 mm mesh) in the flooded areas of the floodplain region. Next, the samples were placed in plastic boxes with water from the collection site, provided with constant aeration by battery-powered air pumps, and transported to the laboratory. The samples were then morphologically identified (shell and internal anatomy), confirmed as *P. dolioides* (Reeve, 1856), and listed in the Mollusc Collection of the Oswaldo Cruz Institute (CMIOC: #11436).

Meat yield

The samples were washed superficially, dried on absorbent paper, measured for total shell length (SL) with a digital calliper (± 0.05 mm), and weighed alive on a digital scale (± 0.001 g). The samples were then divided based on sexual maturity: young (< 35 mm SL) and adult (≥ 35 mm SL).

The samples were sacrificed using the same technique used for "escargot", that is, a 3-day water diet, external cleaning of the shell with running water, and immersion in boiling water (4 min) to separate the viscera and shell from the meat (edible part) for weighing (Barboza and Romanelli, 2005). The meat yield was estimated as the proportion of meat weight (edible part) in relation to the total live weight of each sample, using the formula: $MY = (Mw / Tw) \times 100$ (Vasconcelos *et al.,* 2009), where MY = meat yield (%); Mw = meat weight; and Tw = total (live) weight.

Meat sensory analysis

From the same collection site, 15 adult males and 15 adult females were collected in August 2017. These were reared for reproduction in a laboratory using a 310-L tank with filtration system, closed water circulation, and constant aeration. After five females laid their eggs and these eggs hatched, the juveniles were separated and reared in three tanks of 310 L each, with the same conditions mentioned earlier. During the first 30 days, the juveniles were fed with lettuce (*Lactuca sativa* L.). After this period, they were fed according to the treatments described below. The tanks were siphoned every three days to eliminate leftover food and excretes, thus improving *P. dolioides* development and reducing the mortality rate. The juveniles were cultivated for eight months (December 2017 - August 2018).

The sensory analysis of the meat was based on the following three feeding treatments: Treatment I - fed with aquatic grass *Echinochloa polystachya* (Kunth) Hitch; Treatment II - fed with commercial ration (fish food with 34% crude protein); and Treatment III - fed with grass and commercial ration. Initially, *P. dolioides* were fasted for five days, washed under running water, and brushed. Then, they were slaughtered in a saucepan with heated water. After boiling for 4 min, *P. dolioides* were removed from the shell, and the foot (edible part) was

separated from the rest of the body (operculum and viscera).

The meat was washed under running water, and subsequently washed with distilled water, and later with autoclaved distilled water to eliminate solid residues (stones, sand, soil, etc.) (Barboza and Romanelli, 2005). The meat of each treatment was cooked separately in a saucepan with 3 g of salt for every 300 mL of water for 20 min after boiling (Babalola, 2016). The cooked meat was offered to the sensory panellist to evaluate the organoleptic properties (colour, flavour, texture, and general acceptability).

The sensory analysis of the meat was approved by Plataforma Brasil, a national and unified registry of research involving humans for the entire CEP/CONEP system, #93292618.8.0000.5020. Forty-five randomly recruited panellists, 25 men and 20 women aged from 18 to 45, participated in the sensory analysis. They were individually offered plates containing 2 g of the meat sample of each treatment, identified only by codes, with a glass of water to rinse their mouths after tasting each treatment. The participants did not have contact with each other during the sensory analysis. The colour, flavour, texture, and general acceptability were evaluated using a 9-point hedonic scale: 1 - disliked extremely, 2 - disliked strongly, 3 - disliked moderately, 4 - disliked slightly, 5 - indifferent, 6 - liked slightly, 7 - liked moderately, 8 - liked strongly, and 9 - liked extremely.

Statistical analysis

To compare the meat yield, factorial analysis of variance was performed considering the sex (male or female) and size (young or adult) of *P. dolioides*, followed by the Tukey's test to establish the significant difference between means. The meat yield percentages were transformed into a sine arch for this analysis. Simple linear regression was also used between individual size (SL) and the respective meat yield for males and females, young and adult. For comparing the parameters of these biometric relationships, the allometric equation (Y = aXb) was linearised through log transformation (lnY = lna + blnX). Regression was tested using the *F*-test.

Following the sensory analysis, the frequency of the hedonic scores was assessed for the three-treatment samples. To compare the hedonic values of each parameter (colour, flavour, texture, and general acceptability), the data were initially subjected to the Shapiro-Wilk test for normality. Since the data did not follow a normal distribution, the non-parametric Kruskal-Wallis test was used to compare the scores of each parameter for *P. dolioides* diet treatments. A significance level of $p \leq 0.05$ was adopted for all analyses.

Results

A total of 216 *P. dolioides* were sampled: 105 females (59 juveniles and 46 adults) and 111 males (65 juveniles and 46 adults). The shell length ranged from 6.2 to 68.5 mm (31.9 ± 13.3), of which 105 were females (31.5 ± 13.5) and 111 males (32.4 ± 13.2). Live weight of the females ranged between 0.14 and 49.9 g (8.1 ± 9.5), and live weight of the males ranged between 0.15 and 45.9 g (8.4 ± 9.5). Weight of the meat (edible portion) ranged from 0.01 to 5.7 g (1.0 ± 1.1) for females, and from 0.01 to 5.2 g (1.0 ± 1.1) for males (Table 1). The average meat yield was 11.9 ± 3.4%, ranging from 2.2 to 23.5% (Table 1). No significant difference was found for meat yield in relation to sex (*F*-value = 1.315; *P*-value = 0.252), whereas a statistically significant difference was observed in relation to specimen size (*F*-value = 4.848; *P*-value = 0.029) (Table 2).

The linear relationships established between shell length and meat yield displayed a relatively poor fit (Figure 1). Despite the low determination coefficient (R^2), the meat yield tended to increase with the increase in size of juveniles (SL < 35 mm), and then decreased in adult stage. The relationship between shell length and percentage of meat yield of *P. dolioides* was significant for both young females (*F*-value = 1048.204; *P*-value < 0.0001) and males (*F*-value = 606.305; *P*-value < 0.0001). For adults, the relationship was significant for males (*F*-value = 68.266; *P*-value = 0.012) but not for females (*F*-value = 0.926; *P*-value = 0.657) (Figure 1).

In the sensory analysis, a significant difference was observed between the diet treatments of *P. dolioides* for colour (*H*-value = 87.421; *P*-value = 0.013) and texture (*H*-value = 73379; *P*-value = 0.026). No differences were found for flavour (*H*-value = 42.784; *P*-value = 0.118) and general acceptability (*H*-value = 50904; *P*-value = 0.079).

In the 9-point hedonic scale, the cooked meat of *P. dolioides* obtained an acceptability rate of over 60% for all treatments, with Treatment III reaching 82.2%. Colour yielded the lowest rate of 42.2% in Treatment I, and flavour yielded the highest rate of 86.7% in Treatment III (Table 3).

Discussion

The meat yield of *P. dolioides* was low when compared with other congeneric species such as

Table 1. Minimum (Min.), maximum (Max.), and mean (± standard deviation) of shell length (SL), total weight (TW), meat weight, and meat yield of *P. dolioides* according to sex.

N	Sex		SL (mm)	TW (g)	Meat weight (g)	Meat yield (%)
59	JF	Min.	6.2	0.1	0.1	5.5
		Max.	34.5	7.8	1.2	19.6
		Mean ± SD	21.6 ± 7.8	2.5 ± 2.3	0.3 ± 0.3	10.9 ± 3.3
46	AF	Min.	35.1	5.7	0.7	2.8
		Max.	68.5	49.9	5.7	19.9
		Mean ± SD	44.1 ± 7.3	14.5 ± 9.2	1.8 ± 1.1	12.5 ± 2.8
65	JM	Min.	8.8	0.154	0.1	4.4
		Max.	34.9	6.1	1.1	23.5
		Mean ± SD	23.13 ± 6.9	2.5 ± 1.7	0.3 ± 0.3	12.1 ± 4.2
46	AM	Min.	37.7	5.811	0.8	2.19
		Max.	65.5	45.9	5.2	17.28
		Mean ± SD	45.5 ± 7.3	16.6 ± 9.9	1.9 ± 1.1	12.4 ± 2.2

JF: juvenile female, AF: adult female, JM: juvenile male, and AM: adult male.

Table 2. Analysis of factorial variance of meat yield of *P. dolioides* according to sex and size.

Factor	DF	MS	*F*-value	*P*-value
Sex	1	0.002	1.315	0.253
Size	1	0.005	4.848	0.029
Sex vs Size	1	0.002	2.050	0.153

DF = degree of freedom, and MS = average squares.

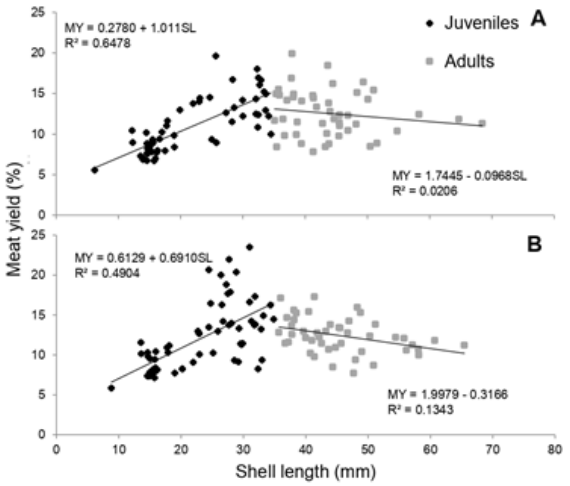

Figure 1. Relationships between shell length (SL) and meat yield (MY) in juvenile (< 35 mm SL) and adult (≥ 35 mm SL) females (A) and males (B) of *P. dolioides*.

cooked *P. lineata* and raw *P. canaliculata* (Serra, 1997) (Barboza and Rommanelli, 2005). On average, individual size played a significant role with smaller individuals providing a lower meat yield. These results differ from those of other studies conducted with *P. lineata*, in which the meat yield in batches of smaller sizes was higher (23.89%) than those of medium (21.25%) and large (23.13%) sizes (Barboza and Rommanelli, 2005). This difference may be related to the period in which *P. dolioides* were collected in the present work, which was during the reproductive season between February and August, as reproduction requires a high energy investment for gonadal maturation and production of gametes (Cichon, 1999), thus influencing the edible content of *P. dolioides* (Vasconcelos *et al.,* 2017). Moreover, low meat yield may also be characteristic of this

Table 3. Mean and standard deviation of sensory scores, and average percentage of panellists giving scores of 6 to 9 for the sensorial attributes of *P. dolioides* meat, according to the feed.

Property	Grass	%	Ration	%	Grass + Ration	%
Colour	5.3 ± 1.6^{a}	42.2	5.9 ± 2.1^{ab}	60.0	6.4 ± 1.8^{b}	64.4
Flavour	6.5 ± 1.4^{a}	77.8	6.7 ± 2.1^{a}	75.8	7.1 ± 1.4^{a}	86.7
Texture	5.9 ± 1.7^{a}	62.2	6.4 ± 1.8^{ab}	75.6	6.7 ± 1.3^{b}	84.4
Acceptability	6.3 ± 1.5^{a}	75.6	6.5 ± 1.8^{a}	68.9	7 ± 1.3^{a}	82.2

Means of the same parameter followed by different lowercase superscripts are statistically different ($p < 0.05$) according to Tukey's test.

species.

The results obtained indicated that *P. dolioides* could be appropriate for cultivation for human consumption despite the low meat yield as compared to other congeneric species. The edible portion of gastropods should be carefully investigated because it can vary depending on the country in which the species are used for human consumption (Vasconcelos *et al.,* 2017). Other factors such as different meat extraction methods (mechanised vs manual) and treatments (raw vs cooked, wet weight vs. dry weight) also influence the yield comparison among different species (Vasconcelos *et al.,* 2009).

The relationship between individual size and meat yield of *P. dolioides* showed positive slope for young individuals, and negative slope for adult individuals of both sexes, thus indicating that loss in meat yield could be associated with the reproductive period (Vasconcelos *et al.,* 2017). Sexual maturity in *P. dolioides* occurs when they reach a shell length of between 25 and 35 mm, depending on food availability and environmental conditions.

The sensory analysis indicated that the *P. dolioides* meat colour received the lowest evaluation score, thus corroborating the findings of Barboza *et al.* (2006) who observed that their panellists were dissatisfied with the dark colour of the meat of *P. lineata* and *A. fulica*. Dark-coloured meat is characteristic in these gastropods, and it does not please final consumers.

Flavour did not significantly differ among the diets fed to *P. dolioides*, and this attribute did not influence the final acceptance of the meat. The same result was found by Omolara and Olaleye (2010) who assessed the organoleptic properties of the meat of *A. marginata* fed with various types of food.

In relation to texture, the results obtained in the present work corroborate the findings reported by Marsyha *et al.* (2018), in which the meal of *P. canaliculata* significantly affected the texture of weaning food. In the organoleptic evaluation of the meat of *A. marginata*, however, no statistical difference was found among treatments with various diets (Marsyha *et al.,* 2018).

The acceptability indexes recorded in the present work, specifically for Treatment III, in which the gastropods were fed with ration and grass, corroborate the findings of Bispo *et al.* (2004) who considered levels above 70% as satisfactory. Thus, to increase the acceptability of the meat of *P. dolioides*, the species should be cultivated with balanced ration and plant fibres.

Conclusion

The meat yield of *P. dolioides* was 11.9 ± 3.4, which was less than the yield previously recorded for other gastropods. The sensory analysis showed that the meat of *P. dolioides* had a satisfactory acceptance rate among the panellists, especially in the case of those fed with balanced ration and plant fibres. Even with low yield, the meat of *P. dolioides* is a source of low-cost protein for people with dietary food limitations and for underprivileged populations of the Amazon region, which also serves as a supplementary income alternative for animal producers since it has not been commercially exploited. Nevertheless, further studies should be performed on the proximate composition and nutritional value of *P. dolioides*.

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