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Morphometric evaluations and yields of commecial cuts of pirarucu (*Arapaima gigas*) in different weight classes

Jucilene Cavali[1,3], Beatriz Andrade Nóbrega[1,2], Jerônimo Vieira Dantas Filho[1]*, Elvino Ferreira[1], Marlos Oliveira Porto[1,3], Rilke Tadeu Fonseca de Freitas[4]

[1] Universidade Federal de Rondônia, Programa de Pós-Graduação em Ciências Ambientais, Rolim de Moura, RO, Brasil. E-mail: jcavali@unir.br; policarpoandrade@hotmail.com; jeronimovdantas@gmail.com; elvino@unir.br; marlosporto@unir.br
[2] Faculdade Estácio São Paulo, Departamento de Nutrição, Rolim de Moura, RO, Brasil
[3] Universidade Federal de Rondônia, Departamento de Zootecnia, Presidente Médici, RO, Brasil
[4] Universidade Federal de Lavras, Departamento de Zootecnia, Lavras, MG, Brasil. E-mail: rilke@ufla.br

ABSTRACT: The aimed of this study was to analyze the yield, correlations, and profitability of different commercial cuts of pirarucu (Arapaima gigas) in seven weight classes. Data on 380 fish were obtained, with weight ranging 4.7 to 48.2 kg. The Kruskal-Wallis's test (α = 0.05) was used to compare the average income. And Spearman's correlation (α = 0.05) was used to verify the correlation between morphometric measurements and yields. To obtain profit in each weight class due to the cut produced, an economic analysis was performed considering the cost of buying the fish. The weight classes 1 (< 8 kg) and 6 (23.1 to 32 kg) had the highest yields and weight classes 1 (< 8.0 kg) and 2 (8.1 to 11.0 kg) the lowest residues production. The yield of fillet mignon and tail fillet is higher in weight classes 4 (14.1 to 18 kg), 5 (18.1 to 23.0 kg) and 6 (23.1 to 32.0 kg), while the yield of loin and residues did not differ between weight classes. The production of the commecial cuts presented a higher economic return than the production of pirarucu deboned in all weight classes, but it is not recommended to take the pirarucu production above 32 kg. The measure of average circumference has a moderately positive correlation with the deboned yield, and can be used to determine the yields of this commercial cut.

Key words: economic viability; fish farming; fish industry; productive yield

Avaliações morfométricas e rendimentos de cortes comeciais de pirarucu (*Arapaima gigas*) em diferentes classes de peso

RESUMO: O objetivo deste estudo foi analisar o rendimento, as correlações e a lucratividade de diferentes cortes comerciais de pirarucu (*Arapaima gigas*) em sete classes de peso. Foram obtidos dados de 380 peixes, com peso variando de 4,7 a 48,2 kg. O teste de Kruskal-Wallis (α = 0,05) foi usado para comparar a renda média. E a correlação de Spearman (α = 0,05) foi para verificar a correlação entre as medidas morfométricas e os rendimentos. Foi obtido valor de lucro em cada classe de peso devido ao corte produzido, e realizada uma análise econômica considerando o custo de compra do pescado. As classes de peso 1 (< 8 kg) e 6 (23,1 a 32 kg) expresseram os maiores rendimentos e as classes de peso 1 (< 8,0 kg) e 2 (8,1 a 11,0 kg) a menor produção de resíduos. O rendimento de filé mignon e filé de cauda é maior nas classes de peso 4 (14,1 a 18 kg), 5 (18,1 a 23,0 kg) e 6 (23,1 a 32,0 kg), enquanto o rendimento de lombo e resíduos não diferiu entre as classes de peso. A produção dos cortes apresentou retorno econômico superior à produção de manta em todas as classes de peso, mas não é recomendável produzir pirarucu acima de 32 kg. A medida da circunferência média tem correlação moderadamente positiva com o rendimento de manta, podendo ser utilizada para determinar os rendimentos desse corte comercial.

Palavras-chave: viabilidade econômica; piscicultura; indústria pesqueira; rendimento produtivo

* Jerônimo Vieira Dantas Filho - E-mail: jeronimovdantas@gmail.com (Corresponding author)
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Introduction

The fish is an important component in the human diet, as a source of proteins, lipids and bioactive components (Batalha et al., 2017). And in this way, the fish industry contributes to the supply of a wide variety of products and by-products (Lustosa et al., 2018). The fish production in the Brazil has been growing consecutively, which is why the country ranks fourth worldwide in the production of farmed fish (Marques et al., 2020). Within this scenario, the Rondônia state is highlighted, occupying the third place in the national ranking of fish farming and first place in the production of native species (Meante & Dória, 2017).

For the Amazon it is essential to encourage the production of native fish, since there are several species of zootechnical interest that can contribute to meet the internal demand for fish (Lustosa Neto et al., 2018). For this, it is necessary to know the species since its acquisition, production, processing, and marketing. In this sense, the pirarucu *Arapaima gigas* Schinz, 1822 (Arapaimidae) has desirable characteristics for breeding in captivity, due to its rapid growth and quality meat (Dantas Filho et al., 2021).

A fish native to the Amazon region, the pirarucu has occupied space in the world trade for having excellent biological and zootechnical characteristics (Malheiros et al., 2016), excellent quality of meat without thorns, enormous acceptance by the population, rusticity for the management, adaptation to air breathing and high growth rate (Cavali et al., 2020). Despite several studies on the cultivation of the species, some important data are still missing, especially on processing. These studies are essential to estimate the potential of specie industrialization, the scale of production and to meet the quality and availability of resources.

According to Luxinger et al. (2018), the yield of fillets with pirarucu skin in weight classes over 30 kg, vary from 56 to 58%. In the case of captive fish, the slaughter weight is usually lower (10-20 kg), which can alter the yield of edible parts. In order to prove these results, studies should evaluate these parameters in different weight classes, since the slaughter weight seems to be directly related to the fillet yield, which can influence the quality and value of the products. Another tool used in several species of fish are the morphometric measures, which, because they are methodologically inexpensive and easy to measure (Luxinger et al., 2018; Mourad et al., 2018), and can therefore be used in the selection of pirarucu breeding stock can produce a greater number of noble commercial cuts (Fernandes et al., 2015).

Given the assumptions presented, the aimed of this study was to analyze the yield, correlations, and profitability of different commercial cuts of pirarucu (*Arapaima gigas*) in seven weight classes.

Materials and Methods

The current research was submitted to the Ethics Committee on Animal Use, at the Universidade Federal de Rondônia (CEUA/UNIR) and was approved with protocol No. 002/2017/UNIR.

Data collections were carried out at two fish processing units in the Rondônia state, Brazil. The fish industries were provided with municipal inspection services (SIM) and federal inspection services (SIF) and located in the municipalities of Ariquemes and Vale do Paraíso, in Rondônia state, Brazil.

The data collections took place between September 2017 and March 2019 and, in all, data from 380 fishes were recorded, with weight ranging 4.7 to 48.2 kg. Classes were established in relation to the body weight of animals linked to the yields of commercial cuts, giving priority to the formation of homogeneous categories. The weight range in each class was determined based on the empirical knowledge of the fish industries, which observe better or worse cut yields depending on the slaughter weight, with the following weight classes being established for the pirarucu: Weight class 1: < 8.0 kg; Weight class 2: 8.1 to 11.0 kg; Weight class 3: 11.1 to 14.0 kg; Weight class 4: 14.1 to 18.0 kg; Weight class 5: 18.1 to 23.0 kg; Weight class 6: 23.1 to 32.0 kg; Weight class 7: > 32.0 kg.

Before the fish started industrial processing, weighing, body measurements and fish identification were carried out using labels attached to the operculum, which accompanied the residues boxes and commercial cuts to the end, allowing sample traceability. The following measures were evaluated: total length (CT), from the anterior end of the head to the end of the fish's tail; standard length (CP), from the anterior end of the head to the end of the caudal peduncle; head length (CC), between the anterior end of the head and the caudal border of the operculum; cranial circumference (CirC), measured at the end of the operculum; medium circumference (CirM), taken in the largest part of the body; and caudal circumference (CirCau), measured in the animal's caudal region (Luxinger et al., 2018).

Pirarucu was processed without opening the abdominal cavity to remove the viscera. The deboned on each side was removed, still attached to the leather and scales, leaving the spine together with the head and all visceral content, which were separated and weighed individually. On the table for commercial cuts, all meat fraction was separated from the leather with the scales, this product being called "pirarucu deboned". The commercial cuts come from the deboned, with the loin located at the top of the pirarucu deboned and fillet mignon is the largest meat part that covers the ribs and the tail fillet that originates in the caudal portion.

In process of separating the pirarucu deboned from the leather, meat parts that were still adhered to the leather were destined for the manufacture of the pirarucu pulp, the minced fish (mechanically separated meat - MSM) by averages of grinding. Throughout the process, all residues and by-products produced in the processing were packed in boxes and weighed on a digital scale with an accuracy of 0.05g. And, using Equation 1, the yields of pirarucu deboned, fillet mignon, loin, tail fillet, MSM and residues were calculated.

$$R\% = \frac{p}{PT} \times 100 \quad (1)$$

where: R% - yield; p - weight of the sample; and, PT - total weight of the fish.

For statistical analysis, Shapiro-Wilk's and Levene's tests ($\alpha = 0.05$) were conducted to verify normality and homogeneity. The Kruskal-Wallis's non-parametric test ($\alpha = 0.05$) was chosen to compare the averages followed by the standard deviation of income between weight classes. To check the correlation between the morphometric measures and the yields, Spearman's correlation coefficient test was performed ($\alpha = 0.05$). Also, an economic analysis was carried out to obtain profit in each of the classes due to the cut produced, considering only the cost of buying the fish, through Equation 2.

$$\text{Profit} = \frac{(PT \times R\% \times p) - (PT \times v)}{PT} \quad (2)$$

where: PT - total weight; R% - cutting yield; p - selling price of the cut by the fish processing unit; and, v - amount paid by the processing unit to the producer.

The software used to carry out the statistical analyzes was the Genes Program made available by the Universidade Federal de Viçosa (UFV), version 13.3 (Cruz, 2013).

Results

Yields of the pirarucu deboned decreased as the weight increased, in weight class 7 (> 32 kg) expressed yield of 11.52%, lower than in weight class 1 (< 8 kg). For fish in weight classes 1 (< 8 kg) to 6 (23.1 to 32.0 kg), the statistics did not presented differences (p>0.05) in the deboned yields, while the residues are less representative in the pirarucu in weight classes 1 (< 8 kg) and 2 (8.1 to 11.0 kg). In contrast, the MSM yield increased directly in proportion to the body weight of the pirarucu, reaching 9.27% for animals in weight class 7 (> 32 kg) (Table 1).

In the assessment of commercial cuts (Table 2), the yield of fillet mignon and tail fillet is higher for fish in weight classes 4 (14.1 to 18.0 kg), 5 (18.1 to 23.0 kg) and 6 (23.1 to 32.0 kg), while for the yield of loin and residues there was no difference (p > 0.05) among fish in the body weight classes. However, MSM presented higher yield for weight class 7 (> 32 kg). The most homogeneous commercial cuts are produced from heavier animals, generally over 14 kg, due to the demands of the consumer market due to the pattern found on the deboned of these animals. These commercial cuts add value to the refrigerator product, instead of selling the whole deboned and, in addition, they are nutritionally special products that can reach certain niche consumer markets.

Table 1. Yield of deboned, MSM and pirarucu residues (*A. gigas*) in different weight classes.

Weight classes	Yield (%)[1]			*n*
	Deboned	MSM[2]	Residues	
1 (< 8.0 kg)	49.79 ± 6.22[a]	0.00 ± 0.00[c]	48.82 ± 4.44[b]	79
2 (8.1 to 11.0 kg)	49.22 ± 6.15[a]	2.16 ± 1.65[b]	49.76 ± 4.52[b]	128
3 (11.1 to 14.0 kg)	46.58 ± 5.82[a]	2.61 ± 2.00[b]	52.64 ± 4.79[a]	68
4 (14.1 to 18.0 kg)	46.97 ± 5.87[a]	2.74 ± 2.10[b]	51.12 ± 4.65[ab]	32
5 (18.1 to 23.0 kg)	45.98 ± 5.74[a]	7.95 ± 6.09[a]	50.32 ± 4.57[ab]	33
6 (23.1 to 32.0 kg)	44.19 ± 5.52[ab]	7.07 ± 5.42[a]	51.30 ± 4.66[ab]	16
7 (> 32.0 kg)	38.27 ± 4.78[b]	9.27 ± 7.10[a]	51.95 ± 4.72[a]	24

[1]In the columns, the averages followed by different letters (a, b, c) are different from each other by the Kruskal-Wallis's test (p < 0.05); [1]Yield of deboned with skin; [2]mechanically separated meat.

It is worth noting the difficulty in handling larger animals such as pirarucu, because the yield of MSM has become very expressive in the heavier classes and MSM comes from the fleshy parts that were attached to the skin in the process of mechanical separation of the deboned cut. The heavier classes are characterized in older animals, possibly a result of inefficient production systems with cultivation time greater than 24 months, which did not present ideal slaughter weight in the first cultive cycle. Older animals are less efficient in muscle deposition whereas they have more red fibers and greater deposition of body fat, affecting the yields of commercial cuts and increasing the yields of slaughter residues.

The average yield of residues from the production of deboned and commercial cuts of pirarucu is 50.93%, representing most of the amount paid by the processing unit to the producer and alternatives to transform these residues into co-products have been used. The production of MSM from the edible regions of pirarucu is routine in all the fish industry, representing up to 10.5% of the total weight of the fish, which provides a high quality food for the preparation of semi-finished products, with functional properties, smooth and free of pimples and bones, which facilitates the use in food, including children and the elderly.

The pirarucu skin (with scales) represents an average of 30.78% of the residues, with the entire piece of animals over 12 kg being marketed. After tanning, pirarucu leather has high added value and has been used in the manufacture of bags, shoes, and accessories, it was even awarded by Première

Table 2. Yields of commercial cuts, MSM and pirarucu (*A. gigas*) residues in different weight classes.

Weight classes	Yield (%)[1]					*n*
	Fillet mignon	Loin	Tail Fillet	MSM[2]	Residues	
4 (14.1 to 18.0 kg)	21.11 ± 5.11[a]	17.08 ± 2.62[a]	8.72 ± 3.48[ab]	4.17 ± 1.82[b]	51.27 ± 3.21[a]	6
5 (18.1 to 23.0 kg)	17.42 ± 4.22[ab]	16.73 ± 2.57[a]	9.33 ± 3.73[a]	7.19 ± 3.14[b]	51.59 ± 3.23[a]	20
6 (23.1 to 32.0 kg)	18.13 ± 4.39[ab]	17.23 ± 2.65[a]	7.22 ± 2.88[ab]	6.41 ± 2.80[b]	49.74 ± 3.12[a]	9
7 (>32.0 kg)	15.32 ± 3.71[b]	15.33 ± 2.35[a]	5.25 ± 2.10[b]	10.47 ± 4.57[a]	51.72 ± 3.24[a]	17

[1]In the columns, the averages followed by different letters (a, b) are different from each other by the Kruskal-Wallis's test (p < 0.05); [1]Yield of deboned with skin; [2]mechanically separated meat.

Vision Paris in 2017 (Fernandes et al., 2015), an international fair that highlights the best and most innovative materials from the fashion market.

For pirarucu deboned, fish in weight classes 1 (< 8 kg) to 5 (18.1 23.0 kg) have the greatest economic return to the fish industry (Table 3). For commercial cuts, animals slaughtered in weight class 4 (14.1 to 18.0 kg) have the highest economic return in the three commercial cuts evaluated, but animals in weight classes 5 (18.1 to 23.0 kg) and 6 (23.1 to 32.0 kg) have also been profitable for the fish industry. Weight class 7 (> 32.0 kg) fish presented less yield for both deboned production and 58% lower profit, compared to other weight classes, as for fillet mignon (50%), loin (38%) and tail fillet (60%).

Pirarucu deboned is considered the most commonly marketed cut, because in addition to being the commercial cut most produced by the processing units, it is a practical product, free of thorns, pleasant and very appreciated flavor, having an average commercial value of US$ 5.11 kg^{-1}. Commercial cuts are made with fish over 14 kg, due to the meat standard and market demand. The loin is the most sophisticated cut, due to the low fat content, muscular structure and soft consistency after preparation, being marketed with an average value of US$ 6.49 kg^{-1}. Fillet mignon is a very tasty meat and richer in fats, being the best type of fillet commercialized and its average value is US$ 5.73 kg^{-1}. Tail fillet is the caudal part of the tail fillet, with more reddish and less standard meat, but no less tasty, with an average commercial value of US$ 5.15 kg^{-1}.

When considering the sale value of the pirarucu deboned and MSM, it is observed that weight class 5 (18.1 to 23.0 kg) generates the highest profit, of US$ 1.09 kg^{-1}, yielding up to US$ 25.15 in a 23 kg fish. However, the production of commercial cuts for pirarucu in weight classes 4 (14.1 to 18.0 kg), 5 (18.1 to 23.0 kg) and 6 (23.1 to 32.0 kg) is indicated, as these together with MSM present a profit of US$ 1.32, 1.18 and US$ 1.13 kg^{-1}, respectively. The pirarucu yield up to US$ 36.04 in a 32 kg fish. Weight classes 1 (< 8.0 kg), 2 (8.1 to 11.0 kg) and 3 (11.1 to 14.0 kg) are the most suitable for the production of deboned and weight class 7 (> 32.0 kg) is the least profitable, generating a profit of US$ 0.61 kg^{-1} of deboned with MSM and US$ 0.82 kg^{-1} of commercial cuts with MSM. It is not recommended to produce pirarucu weighing more than 32 kg, as the residues become more representative.

Pirarucu deboned yield and the CT, CP and CC measurements only expressed a correlation ($p > 0.05$) in weight class 4 (14.1 to 18.0 kg), which was moderately negative. The CirM measure expressed a weak positive correlation with the deboned performance in all weight classes, except for weight classes 5 (18.1 to 23.0 kg) and 6 (23.1 to 32.0 kg), which did not present any correlation coefficient ($p > 0.05$) (Table 4).

There were no correlations ($p > 0.05$) between fillet mignon yield and morphometric measurements, while for loin yield, they were significant only between CP (-0.478*) and CirC (-0.491*) in class 5. Tail Fillet yield showed a high negative correlation with CirM and CirCau in weight class 6 (23.1 to 32.0 kg) and a moderate correlation with CP, CC and CirC (Table 5).

The CirM was the most positively related measure ($p < 0.05$) with the deboned yield in almost all weight classes, but it did not correlate with commercial cuts ($p > 0.05$), except for tail fillet in weight class 6 (23.1 to 32.0 kg), with a determination coefficient of 0.812. The CirC and CirCau measurements were

Table 3. Economic return of the deboned and commercial cuts of pirarucu (*A. gigas*) in different weight classes.

Weight classes	Economic return (US$)*					
	Deboned	MSM¹	Fillet mignon	Loin	Tail Fillet	MSM²
1 (< 8.0 kg)	5.31	0.00	-	-	-	-
2 (8.1 to 11.0 kg)	5.16	0.23	-	-	-	-
3 (11.1 to 14.0 kg)	4.46	0.27	-	-	-	-
4 (14.1 to 18.0 kg)	4.56	0.29	2.86	2.31	1.18	0.56
5 (18.1 to 23.0 kg)	4.81	0.92	2.12	2.04	1.14	0.87
6 (23.1 to 32.0 kg)	3.82	0.73	2.18	2.08	0.87	0.77
7 (> 32.0 kg)	2.23	0.96	1.42	1.42	0.48	0.97

*Profit calculated based on the earnings of each weight class, considering only the pirarucu acquisition value at US$ 1.53 kg^{-1}. ¹MSM from deboned production. ²MSM from the production of commercial cuts.

Table 4. Correlations between the deboned yield and the morphometric measurements in relation to the different weight classes of the pirarucu (*A. gigas*).

Weight classes	Economic return (US$)*					
	CT	CP	CC	CirC	CirM	CirCau
1 (< 8.0 kg)	ns	ns	ns	ns	0.355*	0.355*
2 (8.1 to 11.0 kg)	ns	ns	ns	0.529*	0.515*	0.434*
3 (11.1 to 14.0 kg)	ns	ns	ns	ns	0.593*	ns
4 (14.1 to 18.0 kg)	0.596**	0.725**	0.726**	0.667**	0.665**	0.532*
5 (18.1 to 23.0 kg)	ns	ns	ns	ns	ns	ns
6 (23.1 to 32.0 kg)	ns	ns	ns	ns	ns	ns
7 (> 32.0 kg)	ns	ns	ns	ns	0.450*	ns

* - significant ($p < 0.05$). ** - significant ($p < 0.01$); ns - not significant ($p \geq 0.05$); CT - total length; CP - standard length; WC - head length; CirC - cranial circumference; CirM - medium circumference; CirCau - caudal circumference.

Table 5. Correlations between tail fillet yield and morphometric measurements in relation to different weight classes of the pirarucu (*A. gigas*).

Weight classes	Yield of the tail Fillet					
	CT	CP	CC	CirC	CirM	CirCau
4 (14.1 to 18.0 kg)	ns	ns	ns	ns	ns	ns
5 (18.1 to 23.0 kg)	ns	ns	ns	ns	ns	ns
6 (23.1 to 32.0 kg)	ns	ns	ns	ns	-0.812**	-0.911**
7 (> 32.0 kg)	ns	0.485*	-0.498*	-0.542*	ns	ns

* - significant (p < 0.05). ** - significant (p < 0.01); ns - not significant (p ≥ 0.05); CT - total length; CP - standard length; WC - head length; CirC - cranial circumference; CirM - medium circumference; CirCau - caudal circumference.

less efficient, presenting moderate correlations with the pirarucu deboned yield only for fish slaughtered in weight classes 2 (< 8.0 kg) and 4 (8.1 to 11.0 kg).

Discussion

The terms "pirarucu deboned" and "pirarucu fillet" refer to the same product and may also be with or without skin. Factors such as sex, size and age of the fish can influence the yields obtained from processing after slaughter (Fogaça et al., 2011), in addition to variables intrinsic to the raw material, such as the feed condition of the animals, the stage of development of the gonads and environmental variables in force in the growth phase (Cunha et al., 2014). On the other hand, the processing yield can also vary due to factors extrinsic to the fish, such as the efficiency of filleting machines or the manual skill of the operator of these machines (Batalha et al., 2017). Generally, marine and freshwater species show a fillet with skin yield between 32.8 and 59.8% and, for a skinless Fillet, the average yield is 43.0% (Fogaça et al., 2011).

Regarding pirarucu, there are few studies related to its performance. Martins et al. (2015) evaluating pirarucu captured in the wild, found yield of 57.8% fillet with skin for animals with an average weight of 5.9 kg and for animals with an average weight of 60 kg the yield was 56.56%. Cavali et al. (2020), also reported an average fillet yield of 57% for animals between 30 and 40 kg. Pirarucu deboned yield for fish slaughtered in weight class 7 (> 32.0 kg), was 38.27%, lower than that found in the literature by Cavali et al. (2020). Part of this difference is due to the fact that the deboned evaluated in this study were skinless (except classes 1 and 2), and for animals over 32 kg the skin with scales represents an average of 16.37% of the total weight.

Fogaça et al. (2011) when evaluating three pirarucu weight classes, found no significant difference between the skinless fillet yields of the three weight categories, which obtained an average of 48.62% for fish between 7 and 16 kg, similar to that found in this study for the same weight classes. However, Santos et al. (2018) found an average yield of 41.41% of skinless fillet, with the weight of pirarucu varying between 3 and 9 kg. The knowledge of the proportion of the raw material that will be transformed into final products for sale, as well as the quantity that will be part of the processing residue, allows the logistical planning of the production and the necessary calculations for the assessment of the company's productive efficiency (Ferreira et al., 2020). Thus, the establishment of ideal categories of weight at slaughter and the yields of fish meat, under their different forms of presentation, are of great importance for fish processing units and fish farmers (Cunha et al., 2014; Rodrigues et al., 2019).

The increase in fish production and consumption is directly linked to the need to enable technologies for the reuse of residues generated by the aquaculture industry (Hussein & Mansour, 2018). The organic material originating from fish processing is an economically viable source of high quality proteins, oils, vitamins and minerals (Silva et al., 2020), in addition to containing nutrients that contribute to ecological biodiversity, such as: nitrogen, phosphorus, carbon and potassium (Ghaly et al., 2015). Some processing units in Rondônia state silage residues as an alternative for proper disposal (Cavali et al., 2020). The production of silage has advantages in relation to fishmeal, where it is obtained from simple technologies, there is no need for large investments, it uses low cost material, it can be produced on an artisanal scale, in addition to having reduced odor problems and effluents (Vieira et al., 2015).

The main interest of the fish producer is related to the weight of the fish to be delivered to the fish industry. However, for industry, the most important is the production and yield of fillet, product preparation, types of commercial cuts, in short, the processes that go from slaughter to industrialization and presentation of the product to the consumer (Santos et al., 2018; Rodrigues et al., 2019). In this way, pirarucu is marketed by the weight of the whole fish with an average regional sales value of US$ 1.53 kg^{-1}, and the processing industries prioritize animals weighing at least 8 kg. According to Cunha et al. (2014), depending on the size, peculiarities of the fish, as well as characteristics that the final product must exhibit, different cleaning and cutting techniques are practiced.

According to Valladão et al. (2016), the modernization of the fish industry processes will allow a greater added value to fish products and by-products, in addition to allowing the popularization of the portions made to the consumer market. This is mainly due to the tendency of modern society to prefer the consumption of semi-ready or ready products, of high quality, greater diversity and compatible costs. Thus, alternative strategies that seek to popularize and increase consumption of these products should be studied, in addition to adding value and improving the profitability of companies of interest in fish farming.

One of the main strategies to be considered should be the ways in which fish meat is processed, seeking not only the gutted or filleted form, but also more elaborate or ready-made products such as salted, smoked, canned, sausages, restructured and fermented (Can et al., 2015). In addition, if the product shows good presentation (adequate cuts) and quality packaging, "marketing" strategies will be easily developed, whose search for quality food and easy preparation will be one of the greatest strategies for the food industries (Nguyen et al., 2010; Valladão et al., 2016).

The morphometric characteristics are important parameters for the industrialization of fish, because they are indicative of the conformation of the fillet and the percentage of by-products for the different uses of the meat (Fernandes et al., 2015). Considered as the indirect form of characterization, morphometry is represented as an important procedure to estimate body weights and yields, without the need to slaughter the animal, and can give the idea of the total production of the batch (Silva et al., 2009) for both producer and the processing units. According to Luxinger et al. (2018), this is due to the differential capacity of the accumulation of muscle mass in certain points of the animal's body during its growth, which characterizes the shape of the fish and influences body performance.

Cruz et al. (2012) and Can et al. (2015) states that the morphometric variables as a selection criterion are used when there are high correlations between these and the commercial indices of production value, such as fillet yield, presenting great importance for the processing industry. Body measurements usually have a high phenotypic correlation with body weight and fillet weight and low with fillet yield. Luxinger et al. (2018) observed that for pirarucu deboned weight the morphometric measurements of trunk length, caudal perimeter and larger perimeter expressed significant correlations, with the larger perimeter (equivalent to CirM) showing a strong correlation (0.86).

However, the phenotypic correlations between body measurements or animal weight and meat yields found in the studies are usually very low. Santos et al. (2018) found no values greater than 0.30 for both carcass and fillet yield. The correlation results obtained by Rutten et al. (2004) were also small, < 0.19 (width). Rutten et al. (2004) obtained correlations of 0.38 (head length) to 0.51 (width).

This divergence of results for morphometric measurements correlated to the weight of some body parts is common, because, each species presents a variation in its body shape, Fernandes et al. (2015) and Luxinger et al. (2018) point out that even interspecific specimens have morphological differences. However, generally, the measures and morphometric ratios in pirarucu are directly related to the total weight and weight of the body components (Luxinger et al., 2018; Ramos et al., 2020), while the mantle yield has a moderate relationship with the fish's CirM, and this measure can be a very useful tool.

Conclusions

The production of the commercial cuts demonstrated a higher economic return than the production of pirarucu deboned in all weight classes, but it is not recommended to take the pirarucu production above 32 kg. The measure of average circumference has a moderately positive correlation with the deboned yield and can be used to determine the yields of this commercial cut. It is worth mentioning that the knowledge of the weights that provide less residues production, helps fish farmers to remove animals from the production system at the appropriate time, with lower maintenance costs and reducing impacts on water quality. These animals generate better performance at the fish processing unit, ensuring quality and standardization for the final consumer.

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