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Processing yield and chemical composition of rainbow trout (*Oncorhynchus mykiss*) with regard to body weight

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ABSTRACT. The influence of weight (W) category of the rainbow trout on processing yield and chemical composition of the entire eviscerated fish and fish fillet was analyzed. A completely randomized design was employed for processing variables (W_1 = 300 to 370 g and W_2 = 371 to 440) coupled to a 2 x 2 factorial scheme for the chemical composition (W_1 and W_2 and forms of presentation: fillet and whole eviscerated fish). W_1 showed higher yield for entire eviscerated fish (83.00%) and head (13.27%), but a lower yield for the viscera (17.00%), when compared to W_2. We did not affect abdominal muscle yield, fillet with or without skin, skin percentage and residues. There were significant differences between W for moisture (W_1 = 72.30% and W_2 = 71.15%) and lipids (CP_1 = 7.96% and CP_2 = 9.04%) rates. Fillet moisture contents (73.74%) and crude protein (19.05%) were higher ($p < 0.01$) than for entire eviscerated fish (69.71% and 17.81%, respectively). Ash (2.15%) and lipid (10.48%) rates were higher ($p < 0.01$) for entire fish when compared to those of fillets (1.16% and 6.52%, respectively). The slaughter of fish weighing between 300 and 370 g and their fillets are more adequate for the market.

Keywords: fillet yield, filleting, chemical composition, fish.

Rendimentos do processamento e composição química de truta arco-íris (*Oncorhynchus mykiss*) em relação ao peso corporal

RESUMO. O objetivo deste trabalho foi analisar a influência da categoria de peso (CP) da truta arco-íris sobre o rendimento do processamento e a composição centesimal do peixe inteiro eviscerado e do filé. O delineamento foi inteiramente casualizado para as variáveis do processamento (CP_1 = 300 a 370 g e CP_2 = 371 a 440 g) e em esquema fatorial 2 x 2 para composição centesimal (CP_1 e CP_2 e formas de apresentação (filé e peixe inteiro eviscerado). CP_1 apresentou superior rendimento do peixe inteiro eviscerado (83,00%) e cabeça (13,27%), porém inferior para vísceras (17,00%), quando comparados à CP_2. A CP não influenciou no rendimento dos músculos abdominais, filé com pele e sem pele, porcentagem de pele e resíduos. Houve diferenças significativas entre as CP para os teores de umidade (CP_1 = 72,30% e CP_2 = 71,15%) e lipídios (CP_1 = 7,96% e CP_2 = 9,04%). A umidade (73,74%) e a proteína bruta (19,05%) dos filés foram superiores ($p < 0,01$) do que para peixes inteiros eviscerados (69,71% e 17,81%, respectivamente). Teores de cinzas (2,15%) e lipídios (10,48%) foram superiores ($p < 0,01$) para peixes inteiros em relação aos filés (1,16% e 6,52%, respectivamente). Sugere-se o abate dos peixes com peso entre 300 a 370 g e a apresentação em filé como mais adequada para o consumo.

Palavras-chave: beneficiamento, filetagem, composição centesimal, pescado.

Introduction

The rainbow trout (*Oncorhynchus mykiss*) is a temperate climate fish species which adapted itself to rivers in mountainous regions worldwide and has most of the requirements fish consumers demand. It is one of the most cultivated species of the Salmonidae family since it features excellent qualities for aquiculture and sport fishing (Tabata, 2010). Trout production in Brazil in 2011 amounted to 3,277.2 tons, concentrated in the southern and southeastern regions of Brazil. Entire eviscerated fish, cooled or frozen, or frozen smoked fillets are the several forms of trout commercialization by retailers. The small trout breeders, however, sell them as eviscerated fish, smoked fish or fish paste.

Fish meat processing is basic for the aggregation of value to the prime matter and is greatly appreciated by consumers (Basso et al., 2011). In the case of the fish industry, the quality of fish carcass is a necessary factor to define the preparation process of the products and cuts (Freato et al., 2005). Further, information on the processing yield may be of great help for fish quality control and for the tracing system, with an increase in profits in the processing chain (Galvão et al., 2010). Studies on the effect of weight on yield, especially with regard to the presentation forms of the product to consumers (whole eviscerated fish, carcass, fillet) may greatly improve meat yields and profits.

Fillet and carcass yields depend on several factors, such as size, age, sex, anatomic shape of the body, head size and weight of viscera, skin and fins. The efficiency of the fillet machine and the expertise in handling are aspects that should be taken into account.

Fish are a source of high quality protein, vitamins and essential minerals. They are practically the sole source of long chain polyunsaturated fatty acids such as those of the Omega-3 series (Jabeen & Chaudhry, 2011). Information on fish chemical composition is highly relevant for the standardization of food products based on nutritional criteria. It provides elements for decisions on nutritional characteristics and on the follow-up of industrial processes or research by changes in the chemical components.

Lack of information on yield of the filleting process of the rainbow trout, highly appreciated on the market, triggers interest in current research aiming at the analysis of the influence of body weight on the processing yield and on the chemical composition of the entire eviscerated fish and fillets.

Material and methods

Animals used in the experiment and filleting process

The assay was performed at Tecnotruta S.A. in the state of Espírito Santo, Brazil, and Chemical Analyses were conducted in the Laboratory of Nutrition of the Unesp Aquiculture Center in Jaboticabal, São Paulo State, Brazil.

The trout (*Oncorhynchus mykiss*) used in current experiment were cultivated under an intensive system and fed on commercial ration with 42% crude protein. Sixty-four trout, between 10 and 12 months old, were removed from the processing chain of the abattoir Tecnotruta S.A. The fish were distributed into two weight categories (W_1 = 300 - 370 g and W_2 = 371 to 440 g) to analyze carcass yield. The chemical composition of each weight category was undertaken with fillets (n = 8) and whole eviscerated fish (n = 9).

Fish were slaughtered by thermal shock, eviscerated mechanically, washed, packed one by one in plastic bags and frozen at -20°C. Fish were thawed to facilitate the removal of the spine, ribs and bones. The head, tail, fins (anal, caudal and pectoral) were removed after complete thawing; the spine, ribs and bigger bones were then extracted by a longitudinal cut on the ventral region, and the fillet with the skin was exposed. The skin was removed from the fillet with a knife.

Yields (5) were calculated for total weight of fish (TWF), whole eviscerated fish (WEF), weight of carcass (WC) or carcass without the head, viscera and fins; weight of fillet with skin (WFWS) and without skin (WFOS), weight of abdomen muscles (WAM), weight of the head (WH), weight of the viscera (PV), weight of crude skin (WCS) or skin with scales, and weight of total residues (WTR) or head, viscera, crude skin, fins, spine and bones. All yield rates were calculated according to total weight of the specimen, from which the variables yield of carcass with head (YCH), yield of fillet with skin (YFS) and without skin (YFWS), yield of abdominal muscles (YAM) and yield of percentage of skin (YPS), head (YPH), viscera (YPV) and total residues (YTR) were analyzed.

Analysis of chemical composition

Fillet and whole eviscerated fish were ground separately for the analysis of their chemical composition (moisture, crude protein, lipids, ashes). Samples were packed in plastic bags, tagged and frozen at -20°C until analysis.

Samples were partially thawed, ground in a multiprocessor until a uniform pulp was obtained. Aliquots of the pulp were dried in a buffer at 105°C for 16h until constant weight. Crude protein, lipids and ashes from dried samples were determined according to methodology by AOAC (2005). Crude protein rates were evaluated by the semi-micro Kjeldahl method (Silva & Queiroz, 2002).

Experimental design

Assay was completely randomized, with two treatments (W_1 = 300 - 370 g and W_2 = 371 - 440 g) and 20 replications per treatment to determine the variables of the filleting process. A 2 x 2 factorial scheme was prepared for chemical composition with two weight categories (W_1 and W_2) and two product forms (FA_1 = fillet and FA_2 = whole eviscerated), with different number of replications; the fish or fillet was the experimental unit.

Data underwent analysis of variance (ANOVA) and means were compared by tukey's test at 5%

probability, with Statistical Analysis System (SAS, 2004).

Results and discussion

Average weight of W_1 category fish was 334.00 g, significantly lower ($p < 0.01$) than that of W_2 (405.7 g). Significant differences were reported between W_1 and W_2 for weight results of eviscerated fish, carcass, fillet with or without skin, viscera, skin and total residues. However, fish weighing between 371 and 440 g had higher rates, although weight of head and abdominal muscles did not differ in weight among the categories evaluated (Table 1).

Weight of fish affected ($p < 0.05$) the variables yield of whole eviscerated fish and percentage of head, which were higher for W_1, whereas W_2 indicated higher rates for dress carcass yield and percentage of viscera (Table 2). Rates of yield of abdominal muscles, fillet with or without skin, percentage of skin and total residues did not differ for the weight categories ($p > 0.05$).

Yields for whole eviscerated fish and for fish with and without skin were higher for fish of weight category W_2 when compared to W_1 fish. There was a 52 g increase for whole eviscerated fish, 41.6 g for fillet with skin and 3.45 g for fillet without skin, with a respective yield increase of 1.76, 2.32 and 3.14% for these commercial cuts.

There was a lower yield for whole eviscerated fish in W_2 when compared to W_1, due to the fact that W_2 fish had a greater viscera weight (76.5 g) and consequently a greater visceral percentage (18.8%). On the other hand, the yield of dressed carcass was higher for W_2 (63.3%) probably due to a lower percentage of the head (11.1%). In fact, smaller fish also had a greater head/trunk (body) ratio and as these body parts increased, the ratio decreased.

Yield of whole eviscerated fish may also be calculated by carcass yield. Similar to what have been reported in current paper, Brito et al. (2014) also registered a high carcass yield in the small-sized *Loricariichthys anus*, as for the pacu (*Piaractus mesopotamicus*) by Basso et al. (2011). This characteristic may be related to the evolution of the gonadal development since the gonad size increases with the growth of the animal due to the reproductive period (Brito et al., 2014). Further, carcass yield also depends on the animal's sex. Reidel et al. (2010) reported that carcass yield of male jundiás (*Rhamdia quelen*) was higher than that of females.

There was no significant difference between weight categories for yield of fillets with or without skin. Fish with a small head and viscera percentage tend to have a greater fillet yield. However, the above was not reported in current experiment, perhaps due to the fact that W_1 fish had a great head percentage than those of W_2 (with a 2.16% increase), whereas viscera percentage in W_2 was greater than that in W_1 (1.75% increase).

Table 1. Mean rates for weight of entire eviscerated fish (g), weight of fillet with and without skin (g) and weight of fillet byproducts (g) of the rainbow trout (*Oncorhynchus mykiss*).

Variables	Weight category W_1 (300 - 370 g)	Weight category W_2 (371 - 440 g)	Test F	C.V. (%)
Body weight (g)	334.00 ^{B}	405.75 ^{A}	177.14**	4.61
Whole eviscerated (g)	277.25 ^{B}	329.25 ^{A}	155.98**	4.34
Dressed carcass (g)	204.75^{B}	256.75^{A}	123.98**	6.40
Head (g)	44.25 ^{A}	45.00 ^{A}	0.15^{NS}	13.67
Abdominal muscle (g)	6.96^{A}	6.73 ^{A}	0.07^{NS}	41.79
Fillet with skin (g)	151.4^{B}	193.00^{A}	27.37**	14.60
Fillet without skin (g)	127.20 ^{B}	166.85 ^{A}	29.06**	15.82
Skin (g)	21.30^{B}	24.75^{A}	12.92**	13.18
Viscera (g)	56.75^{B}	76.50^{A}	28.68**	17.51
Total residue (g)	206.80^{B}	238.90^{A}	16.43**	11.24

^{A,B}- in each line, averages followed by the same letter did not differ by tukey's test ($p > 0.05$) ^{NS}- not significant ($p > 0.05$) ** - significant ($p < 0.01$).

Table 2. Mean rates of yield in the two weight categories for the rainbow trout (*Oncorhynchus mykiss*).

Weight category	Whole eviscerated (%)	Dressed carcass (%)	Head (%)	Abdominal muscle (%)	Fillet (%) With skin	Fillet (%) Without skin	Skin (%)	Viscera (%)	Total residues (%)
W_1 (300-370 g)	83.00^{A}	61.30^{B}	13.27^{A}	2.11^{A}	45.29^{A}	38.03^{A}	6.38^{A}	17.00^{B}	58.85^{A}
W_2 (371- 440 g)	81.24^{B}	63.30^{A}	11.11^{B}	1.64^{A}	47.61^{A}	41.17^{A}	6.09^{A}	18.76^{A}	61.97^{A}
Test F	4.77*	4.24*	15.05**	3.08^{NS}	1.24^{NS}	2.61^{NS}	1.58^{NS}	4.76*	2.56^{NS}
C.V.(%)	3.12	4.92	14.46	44.62	14.16	15.53	11.63	14.33	10.21

^{A,B}- in each line, averages followed by the same letter did not differ by tukey's test ($p > 0.05$) ^{NS}- not significant ($p > 0.05$) ** - significant ($p < 0.01$).

Galvão et al. (2010) report fillet yield in fish is closely related to condition factor and head proportion. Moreover, yields in farmed fish may also be influenced by culture conditions such as feed, water temperature and breeding structures (Borderías & Sánchez- Alonso, 2011).

Results follow those reported by Souza et al. (1999) who found that that there was no increase in the yield of whole fish and in fillet without skin in four weight categories of *Oreochromis niloticus*. Souza and Maranhão (2001) analyzed two weight categories (300 - 400 g and 401 - 500 g) for *O. niloticus* and reported that there was only a yield increase for whole eviscerated fish in the highest category. However, Souza et al. (1999) registered that there were higher fillet yields in *Clarias gariepinus* for the biggest fish.

In the case of Thailand tilapia (*Oreochromis* spp.), average filleting yield was 31.0%, ranging between 28.9 and 33.6%, supplemented by 36.0% for head and viscera, 8.0% for skin, 22.0% for bone residues and 3.0% for other wastes (Pinheiro et al., 2006). Carneiro et al. (2004) detected a 29.5% rate for fillet yields in jundiá juveniles (*Rhamdia quelen*), weighing between 201 and 300 g.

The coefficient of variation for the yield of whole eviscerated fish reached 3.12%, and indicated that the variation for yield characteristics is generally less in farmed fish.

Ventral abdominal muscles are normally non-commercial wastes but represent a section varying between 0.79 and 4.36% in current experiment. Although there is no significant difference of the variable between weight categories, the amount, albeit small, is somewhat considerable, and represents an economical increase for the fish breeder or for the fish industrial unit. In fact, muscles may be commercialized as snacks. However, in their research on the Nile tilapia (*O. niloticus*), Souza and Maranhão (2001) reported significant differences between weight categories for the ventral abdominal muscles, with higher rates (3.17 and 3.51%) than those for the rainbow trout. The above reveals that the weight of the muscles may be related to the species and probable due to the lack of standardization of cuts. The high coefficient of variation (44.62%) may be explained by the lack of standardization of cut limits. Losekan et al. (2008) showed that the yield of abdominal muscle in jundiás (*R. quelen*), fed on diets with different types of oil, was approximately 8%, a rather common feature for hide fish.

Head, fins, skin and viscera are wastes, even though the crude skin, or rather, the byproduct of filleting, may be commercialized as prime matter for tanning. Thus, the commercialization of the skin-less fillet is more viable as far as the skin represents a source of alternative yield. In current assay, the percentage of crude skin ranged between 6.1 (W_2) and 6.4% (W_1). Skin percentages did not differ between the weight categories analyzed.

According to Bombardelli and Sanches (2008), the viscera of the granulated catfish (*Pterodoras granulosus*), weighing between 551 and 1000 g, are 17.7% of the entire fish. Results in current experiment with the rainbow trout were similar to those mentioned by these authors. High percentage rates of total residues are actually a concern within the context of environmental pollution which may be decreased by its use as a kind of silage and thus a source of profit and supply of prime matter for the preparation of diets in animal feed.

Comparing data between weight categories showed significant differences ($p < 0.01$) and ($p < 0.05$), respectively for moisture and lipid percentages. Moisture was higher in W_1 and lipid percentage was higher in W_2. However, there was no significant difference for protein and ashes. With regard to the presentation of the fish (fillet or whole eviscerated), there was a significant difference for all chemical composition variables under analysis. Moisture and protein rates were higher ($p < 0.01$) in fillets when compared to those in the whole eviscerated fish. However, ash and lipid percentages in the whole eviscerated fish were higher ($p < 0.01$) (Table 3). There was no interaction between weight categories (W_1 and W_2) and presentation type (whole eviscerated and fillet) for chemical composition.

Table 3. Mean rates* of the chemical composition of fish fillet and whole eviscerated fish in two weight categories of the rainbow trout (*Oncorhynchus mykiss*)

	Moisture (%)	Cruse protein (%)	Lipids (%)	Ashes (%)
Weight category				
W_1 (300 - 370 g)	72.30^A	18.42^A	7.96^B	1.70^A
W_2 (371 - 440 g)	71.15^B	18.43^A	9.04^A	1.61^A
Presentation form				
Fillet	73.74^A	19.05^A	6.52^B	1.16^B
Whole eviscerated	69.71^B	17.81^B	10.48^A	2.15^A
Test F				
Weight category	8.05**	0.0006^{NS}	5.31*	4.14^{NS}
Presentation form	99.42**	21.89**	70.56**	465.70**
Interaction (WC x PF)	0.18^{NS}	0.35^{NS}	0.24^{NS}	2.78^{NS}
C.V. (%)	1.62	4.12	15.47	7.73

A,B- in each line, averages followed by the same letter did not differ by tukey's test ($p > 0.05$) NS- not significant ($p > 0.05$) ** - significant ($p < 0.01$) * rates based on humid weight.

Variations in the fish's chemical composition are closely related to ration intake since protein rates in the muscle tissue slightly increase during the feed period and consequently fat rates have a sharp and fast increase (Boran & Karaçam, 2011). Young fish, the smallest within the species, generally have higher moisture and lower lipid rates than adults. In current assay fish at W_2 had greater lipid and lower moisture rates. Such a difference was expected: as the animal reaches a certain weight, growth rate decreases and fat deposits in the carcass are intensified.

There was no significant difference in protein and ash rates for weight categories, perhaps related to the amplitude range of each studied category or even to the amplitude analyzed only for fish weighing between 300 and 440 g. According to Rasmussen and Ostenfeld (2000), they are actually fish in the same development or growth period, with a small variation in protein rates.

As regard to the presentation forms, namely, whole eviscerated fish and fish fillet, results for moisture (69.7 and 73.7%), crude protein (17.8 and 19.1%), ashes (2.2 and 1.2%) and lipids (10.5 and 6.5%) rates were coherent to those reported by Rasmussen and Ostenfeld (2000). These authors researched the same species, mean weight 261g, and determined moisture (70.2%), protein (16.9%), ash (2.4%), lipids (10.1%) rates for the whole fish, whereas rates for fillets respectively amounted to 73.8, 19.5, 1.5 and 4.9%. Tawfik (2009) reported 77.8, 20.0, 0.24 and 1.5%, respectively for moisture, protein, lipids and ash for the *Carangoides fulvoguttatus*.

According to Rasmussen and Ostenfeld (2000), a greater variation occurs in lipid contents in the fish body when compared to protein rate. This fact may be observed in current assay since the coefficient of variation for lipid rates was higher (15.5%) when compared to that of protein (4.1%), or rather, a greater variability in the amount of lipids between the specimens.

The chemical composition of fish meat depends on biotic and abiotic factors related to the species and culture, such as age, season, sex, gonadal development and diet (Burkert et al., 2008) which affected the physical and organoleptic characteristics and shelf life of fish and derivatives (Burkert et al., 2008).

Fish are normally classified according to their fatty contents, or rather, lean fish (fat rate less than 5%); moderately fat fish (fat rate between 5 and 10%) and fat fish (over 10% fat) (Jabeen & Chaudhry, 2011). The above classification is relevant since lipid rates affect significantly the productive performance, shelf life of the products and consumer's general acceptance. The rainbow trout was classified as moderately fat. In fact, the trout is an intermediate fish in protein (15 - 20%) and fat (5 - 15%), with results for the same variables between 17.81, 19.05 and between 6.5 and 10.5%, respectively, for fish fillet and whole eviscerated fish.

According to Berge and Storebakken (1991), the capacity of accumulating fat on the carcass, coupled to diets with high fat rates may give rise to problems in fish commercialization because of fat deposits on the bones and fins. Further, there is a differential deposit in all the muscles with a high proportion on the abdominal region (Helland & Grisdale-Helland, 1998). High fat rates on these parts may be undesirable if these body segments are included in the presentation form of the product on the market (Helland & Grisdale-Helland, 1998).

Low ash percentage in the fillet (1.2%) occurs because of the reduction in fish bones and the lack of the spine and head bones when compared to that of the whole eviscerated fish (2.15%). According to Rasmussen and Ostenfeld (2000), ash rates of fish range between 0.8 and 1.4%, but may exceed this percentage due to the number of intramuscle fish bones in the fillet. The same author reports that fresh water fish have greater fluctuations, ranging between 0.98 and 3.29%.

The chemical analysis of fresh water fish provides useful information for nutritionists interested in sources with low fat rates and high protein quality. This is also useful so that processing industries develop safer and quality fish products (Jabeen & Chaudhry, 2011). Further, yield rates of several products produced by the minimum processing of different fish species are highly relevant for industries involved in this segment of the pisciculture production chain (Carneiro et al., 2004).

Conclusion

Results indicated that, due to the presentation form of the fish product to the consumer, fish may be slaughtered when weighing 300 - 440 g, for fillets with or without skin. If the whole eviscerated fish is sold, the fish should belong to W_1; in the case the carcass should be sold, the fish should belong to W_2 due to its higher yield. Fish served as fillets contain higher protein rates and lower lipid rates and thus more appropriate for consumption. When only the lipid rates are taken into account, W_1 fish should be slaughtered due to low fat rates.

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