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FOOD TECHNOLOGY

Body composition and sensory quality of wild and farmed brown-trout (*Salmo trutta*) and of farmed rainbow-trout (*Oncorhynchus mykiss*)

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ABSTRACT: *Body composition (total crude protein, lipid, ash, dry matter and moisture) and fatty acid profiles were compared between wild and farmed brown trout and between farmed rainbow trout. Farmed brown trout contained the highest amount of crude protein (18.39%), whereas farmed rainbow trout contained higher levels of crude lipid (2.35%). Thirty six fatty acids were found, including sixteen saturated fatty acids (SFA), nine monounsaturated fatty acids (MUFA) and eleven polyunsaturated fatty acids (PUFA). The most abundant SFA in all fish were palmitic acid and stearic acid. However, the most abundant fatty acids in all trout samples were MUFA and PUFA. MUFA were the most abundant fatty acid in farmed brown trout because of high abundance of oleic acid in this samples (35.46g / 100g fatty acids). PUFA were predominating in the samples of wild brown trout and of rainbow trout 56.16 and 56.29g/100g fatty acids, respectively). Linoleic acid was the most abundant fatty acid reported in the rainbow trout (47.17g/100g fatty acids). Significantly higher amounts of docosahexaenoic acid, α-linolenic acid, arachidonic acid and eicosapentaenoic acid were observed in the wild trout samples. Wild brown trout contained significantly more docosahexaenoic acid, α-linolenic acid, Eicosapentaenoic acidArachidonic acid. Sensory quality evaluation, by a consumers' panel, revealed all samples were equally well accepted.*
Key words: *Salmo trutta, Oncorhynchus mykiss, body composition, fatty acid composition, sensory quality.*

Composição corporal e qualidade sensorial de truta-fário selvagem e cultivada (*Salmo trutta*) e de truta- arco-íris cultivada (*Oncorhynchus mykiss*)

RESUMO: *A composição corporal (teores de proteína, gordura total, cinzas, matéria seca e humidade) e os perfis de ácidos gordos da truta-fário (selvagem e proveniente de aquacultura) e da truta-arco-íris (cultivada) foram comparados. A truta-fário cultivada continha a maior quantidade de proteína bruta (18,39%), enquanto a truta arco-íris possuía teores mais elevados de lípidos (2,35%). Foram detectados 36 ácidos graxos, incluindo 16 ácidos graxos saturados (SFA), nove ácidos graxos monoinsaturados (MUFA) e 11* ácidos *graxos poliinsaturados (PUFA). Os SFA mais abundantes foram o ácido palmítico e o ácido esteárico. No entanto, os ácidos graxos mais abundantes em todas as amostras de truta foram os MUFA e os PUFA. A grande abundância de ácido oleico existente nas amostras de truta-fário cultivada (35,46g/100g de ácidos graxos) faz com que os MUFA sejam os ácidos graxos mais abundantes nesta variedade de truta (42,43g/100g de ácidos graxos) Nas amostras de truta-fário selvagem e nas de truta arco-íris predominaram os PUFA (56,16 e 56,29g/100g de ácidos graxos, respetivamente), sendo o ácido linoleico o mais abundante na truta-arco-íris (47,17g/100g de ácidos graxos). Nas amostras truta-fário selvagem foram observadas quantidades significativamente mais elevadas de ácido docosahexaenóico, ácido α-linolênico, ácido acidoaraquidônico e ácido eicosapentaenóico. Todas as amostras foram igualmente bem aceitas por um painel de consumidores.*
Palavras-chave: *Salmo trutta, Oncorhynchus mykiss, composição corporal, composição em ácidos graxos, qualidade sensorial.*

INTRODUCTION

Because of its healthy and nutritious qualities fish plays a major role in human food (RASMUSSEN, 2001; ASGHARI et al., 2014; CLARET et al., 2014). Since many natural fish stocks are overfished, traditional fisheries cannot meet the current consumer demanding. Giving these circumstances, aquaculture can be the most suitable alternative to traditional fishing to gradually meet consumer demand. From 2003 to 2008 farmed fish production increased 6.8% annually and in a near future it is estimated, that more than 50% of the commercialized fish is from aquaculture production FAO (2014).Therefore, consumers currently have the possibility to buy either wild or farmed fish of the same species without significant differences concerning their price (VALDERRAMA & ANDERSON 2013). However, a question arises: Which fish to consume: wild or farmed fish? Indeed, the definition of quality presupposes a set of features that are difficult to define (OKEN et al., 2012; CLARET et al., 2014;RICKERTSEN et al., 2017). Sensory analysis makes possible define those features by evaluating

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the acceptability/preference of consumers for wild or farmed fish. Nevertheless, the available research comparing wild and farmed trout is mostly focused on the chemical composition and nutritional quality. Concerning the studied trout species, only POHAR (2011) and OZOGUL et al. (2013) attempted to compare the organoleptic qualities of wild and farmed brown-trout, using sensory tests with panels of tasters and/or consumers in order to evaluate if putative differences in their chemical composition would be detected and might influence consumers' choices. Therefore, the objective of the present research was to compare the body composition (moisture, ash, dry matter, total protein and fat contents and fatty acid profile) and sensory qualities of wild and farmed wild and farmed brown-trout (*Salmotrutta*). Besides, the body composition and sensory qualities of farmed rainbow-trout (*Onchorynchusmykiss*) were also compared with wild and farmed brown-trout.

MATERIALS AND METHODS

Twenty wild brown-trout (average body mass (g): 95.4±69.4; average total length (cm): 20.8±4.4) were caught in August by electrofishing in Baceiro River (Bragança, Portugal; 41º55'57''N, 6º50'55''W). Also twenty farmed brown-trout (average body mass (g): 240.4±42,7; average total length (cm): 27.3±1,9) were reared in Castrelos Fish farm and were feed with a dry extruded and pelleted commercial trout diet (AQUASOJA®, 40% crude protein, 16% crude lipid, 8.5% of crude ash, NEF 6.3% and 20KJ/g gross energy).

Both wild and farmed trout were slaughtered by immersing them in a mixture of ice and water (hypothermia). Twenty rainbow-trout (this fish is not native to Portuguese freshwater and consequently, there are no viable wild populations) were obtained in the local market (average body mass (g): 227.5±40.4; average total length (cm): 28.2±1.6). All fish were packaged at vacuum and stored at -18°C to -20°C and were analyzed over a period of three weeks. Moisture, crude ash, crude dry matter, crude protein, crude lipid and fatty acid profile were determined. Total moisture (NP 1614:2002– ISO 1442:1197), crude dry matter, crude ash (NP 1615: 2002–ISO 936:1998) and crude protein (Kjeldahl N×6.25) (NP 1612:2002 - ISO 937:1978) determinations were carried out according to Portuguese norms (NP) with recommended standards by International Organization for Standardization (ISO) correspondences. Crude lipids were extracted from 50g of sample according to the FOLCH et al. (1957) procedure. Fifty milligrams of fat were used to determine the fatty acid profile. Fatty acid were trans esterified according to the procedure described by DOMÍNGUEZ et al. (2015) and as follow: 4mL of a sodium methoxide (2%) solution were added to the fat, vortexed every 5min during 15min at room temperature, then 4mL of H2SO4: methanol solution (1:2), vortexed a few seconds and vortexed again before adding 2mL of distilled water. Organic phase (containing fatty acids methyl esters) was extracted with 2.5mL of hexane. Separation and quantification of the FAMEs were carried out using a gas chromotograph (Shimadzu GC-2010 Plus with an Auto Injector AOC–20i, Kyoto Japan) and using a Supelco® fused silica capillary column (100m-0.25mm-0.2µm film thickness). Chromatographic conditions were as follows: initial column temperature 120°C, maintaining this temperature for 5min, programmed to increase at a gradient of 15°C/min and the injector and detector were maintained at 280°C. Nitrogen, Hydrogen and synthetic Air pure were used as the carrier gases and the tridecanoic acid (C13H26O2) as internal standard was added to the samples prior methylation. FAMEs were identified comparing their retention times with those of authenticated standards (Supelco 37 Component FAME Mix). Data were expressed in g/100g of total fatty acids. All analyses were performed in triplicate.

To evaluate the consumer's preferences, a panel was constituted and formed by 74 students and staff of Polytechnic Institute of Bragança, randomly selected and with no training. On the day before the sensorial test, the samples were thawed in the refrigerator at 4ºC. They were then washed in tap water to remove traces of blood and viscera. Subsequently 1.5% of salt was applied to each specimen and was wrapped in previously encoded aluminum sheet and put into a preheated oven at 150ºC. Cooking time was set by the time they reached 100°C in the innermost part of the sample. After cooking and already devoid of skin and pimples, each of the fish samples were prepared in appropriately standardized subsamples in pieces of approximately 2cm/2cm and wrapped in aluminum foil and placed in a water bath for the maintenance of the temperature and properly codified a three-digit number. At least 25 consumers, in 3 different sessions, were randomly selected to participate in the sensory analysis. The samples were served individually and in a way that the interviewee did not know the species that was being consumed. Each sample exchange was served a glass of water to clear the taste buds. Each sample was evaluated for liking degree using a hedonic 10cm scale (0 corresponded to «completely dislike», 10 corresponded to «completely like»), considering the following variables: appearance, taste, texture, and overall acceptability.

Differences between body and fatty acid composition as well as consumers preferences were analyzed by one way ANOVA test. Tukey test was used to determine significant differences. All statistical differences were considered significant at a level of $P<0.05$.

RESULTS AND DISCUSSION

Compositional analyses of farmed and wild brown trout and of rainbow trout are depicted in table 1. Rainbow trout composition was very similar to farmed brow trout excepting crude protein, which yielded value was similar to the obtained for wild brown trout. Both farmed trout yielded higher values of crude lipids than wild brown trout. The reported results are in line with the findings of KAYA & ERDEM (2009) and KAYA et al. (2014) for both farmed and brown trout and of YEŞILAYER & GENÇ (2013) and OZ & DIKEL (2015) for rainbow trout. Contrarily, to the expected the amount of crude protein reported in rainbow trout was similar to wild brown trout. Indeed, OZ & DIKEL (2015) also reported a lower amount of crude protein in farmed rainbow trout. Nevertheless, according to criteria defined by ANDRADE & LIMA (1975) both- brown trout wild/ farmed and rainbow trout can be classified as semi-fatty (77.2% moisture, 19.0% crude protein, 2.5% crude lipid and 1.3% ash) or lean fish (81.8% moisture, 16.4% protein, 0.5% lipid and 1.3% ash).

Thirty six fatty acids were reported, including sixteen SFA, nine MUFA and eleven PUFA (Table 2). Similarly to results obtained by several authors (KAYA & ERDEM 2009; YEŞILAYER & GENÇ 2013, OZ & DIKEL, 2015; GOEBEL et al., 2016; GULLER et al., 2017) the largest amounts of total SFA were reported both in wild and farmed brown trout. In the present study palmitic acid was identified as the predominant SFA in all trout, being the highest content reported in farmed brown trout (16.64g/100g of total fatty acids). Other major SFA was the stearic acid, which major concentrations were detected in wild brown trout fillets (4.21g/100g of total fatty acids). Nevertheless, farmed brown trout fillets were dominated by MUFA (mainly oleic acid: 35.46g/100g of total fatty acids), whereas both in wild brown trout and rainbow trout fillets PUFA were predominant (58.16 and 56.19g/100g of total fatty acids, respectively). However, rainbow trout fillets composed mainly by acid linoleic (41.17g/100g of total fatty acids), while wild brown trout fillets were dominated by docosahexaenoic, eicosapentaenoic and arachidonic acids (21.14, 16.74 and 5.92g/100g of total fatty acids, respectively). In general, these findings are in line with the data obtained by KAYA & ERDEM (2009); HARLIOĞLU (2012)YEŞILAYER & GENÇ (2013); OZ & DIQUEL (2015); GULLER et al. (2017). In the present research it was not possible to obtain information concerning the diet composition of both farmed trout in order to investigate the plausibility of the observed differences in the fatty acids composition being related to distinct diet composition. Indeed, this hypothesis is corroborate by several literature concerning the effects of mainly vegetable-derived diets versus mainly fish - derived diets on the farmed fish fillet fatty acid composition (e.g. SÉROT et al. 2002; LAZZAROTTO et al. 2018; TURCHINI et al 2018¸YILDIZ et al. 2018). Similarly, the observed differences concerning higher concentrations of docosahexaenoic acid (C22:6 n-3), eicosapentaenoic acid (C20:5n-3) and arachidonic acid (C20:4n-6) in wild trout fillets can be explained by differences between natural and commercial diets. In farmed fish, these PUFA are generally lower than

Table 1 - Comparison of fillet composition (Means±SD and significance) of wild and farmed brown trout and of rainbow trout.

Parameters	brown trout (farmed)	brown trout (wild)	rainbow trout (farmed)	Significance
Crude ash (%)	1.21 (0.03)	1.26 (0.02)	1.21 (0.03)	NS
Moisture (%)	77.75 (0.28)^{A}	80.27 (0.15)^{B}	77.89 (0.53)^{A}	***
Crude drymatter (%)	22.25 (0.28)^{A}	19.73 (0.15)^{B}	22.11 (0.53)^{A}	***
Crude protein (%)	18.39 (0.24)^{A}	17.84 (0.27)^{B}	17.42 (0.39)^{B}	*
Crude lipid (%)	1.55 (0.08)^{A}	0.65 (0.06)^{B}	2.35 (0.18)^{C}	*

A≠B≠C; * significant for $P<0.05$ and ***significant for $P<0.001$; NS not significant.

Table 2 - Comparison of SFA, MUFA and PUFA composition in fillets of wild and farmed brown trout and of rainbow trout. (Means± SD and significance). The fatty acids representing less than 0.10% in all batches were not included in the table.

SFA (g/100g of total fatty acids)	brown trout (farmed)	brown trout (wild)	rainbow trout (farmed)	Significance
C14:0	1.62±0.06^A	0.68±0.06^B	0.63±0.10^B	***
C15:0	0.28±0.04^A	0.22±0.02^A	0.13±0.02^B	*
C16:0	16.64±0.14^A	15.33±0.02^B	12.11±0.36^C	***
C17:0	0.27±0.01^B	0.62±0.01^A	0.180±0.00^C	***
C18:0	3.74±0.04^B	4.21±0.05^A	3.14±0.03^C	***
C20:0	0.07±0.009	0.07±0.01	0.12±0.07	NS
C21:0	0.02±0.01	0.02±0.01	0.017±0.01	NS
C22:0	0.05±0.04^B	0.03±0.03^B	0.17±0.02^A	***
Total SFA	22.74±0.22 ^{A}	21.32±0.06 ^{A}	15.78±1.05 ^{B}	***
MUFA (g/100g of total fatty acids)				
C16:1 n-7	4.26±0.21^A	3.82±0.05^A	0.97±0.24^B	***
C17:1n-7	0.15±0.01^B	0.29±0.05^A	0.12±0.01^B	***
9t -C18:1	0.21±0.03^A	0.10±0.01^B	0.07±0.00^B	***
C18:1 n-9	35.46±0.69^A	15.50±0.10^C	24.43±0.13^B	***
C20:1 n-9	1.19±1.04	0.53±0.02	0.46±0.27	NS
C22:1 n-9	0.71±0.04^A	0.16±0.03^B	0.18±0.01^B	***
C24:1 n-9	0.10±0.10	0.09±0.01)	0.04±0.05	NS
Total MUFA	42.13±0.2 ^{A}	20.56±1.83 ^{B}	26.29±0.30 ^{B}	***
PUFA (g/100g of total fatty acids)				
C18:2 n-6	14.43±0.14^B	6.71±0.66^C	41.17±1.42^A	***
C18:3 n-6	0.43±0.01^B	0.15±0.02^B	2.11±0.29^A	***
C18:3 n-3	1.88±0.05^C	5.05±0.25^A	2.55±0.03^B	***
C20:2 n-6	0.62±0.27^B	0.48±0.09^B	1.04±0.11^A	*
C20:3 n-6	0.90±0.03^B	0.88±0.07^B	1.34±0.06^A	***
C20:3 n-3	0.30±0.03^B	0.41±0.01^A	0.08±0.01^C	***
C20:4 n-6	0.99±0.06^B	5.92±0.29^A	1.22±0.13^B	***
C22:2 n-6	0.45±0.01^B	0.68±0.05^A	0.14±0.01^C	***
C20:5 n-3	2.78±0.05^B	16.74±0.44^A	1.38±0.16^C	***
C22:6 n-3	11.93±0.25^B	21.14±1.99^A	5.26±0.50^C	***
Total PUFA	34.70±0.42^A	58.16±1.93^B	56.29±1.30^B	***
Total n-6	17.82±0.15 ^{A}	14.81±0.17 ^{B}	47.02±1.42 ^{C}	*
Total n-3	16.89±0.23 ^{A}	43.34±1.73 ^{B}	9.27±0.56^C	*
n-6/n-3	1.05±0.01^A	0.34±0.02^B	5.10±0.40^C	*

A≠B≠C; * significant to $P<0.05$ and ***significant to $P<0.001$; NS not significant.

that of wild fish because of possibly lack of lipids originating from phytoplankton and aquatic organisms in farmed fish diets (ACKMAN & TAKEUCHI, 1986; SOUMELA et al., 2016). However, in wild brown trout, fatty acid composition can be even more variable an unpredictable as a consequence of a large genetic, fish size and physiological diversity range and of the exposure to a large ecological heterogeneity (RASMUSSEN, 2001; KAYA & ERDEM 2009; SOUMELA et al.2016; YEŞILAYER & GENÇ, 2013; OZ & DIKEL, 2015; GULLER et al., 2017). Besides, wild brown trout have a broad carnivorous diet composed by larval and adult insects as well as crustaceans, annelids, and gastropods and, sometimes, by other fish. Furthermore, wild brown trout feeding behavior is directly related to age and seasonal abundance of prey (TEIXEIRA & CORTES, 2006; BOSCO et al., 2013).

The ratio of n-6 to n-3 was significantly lower in wild brown trout. These results were in line with the literature in general (e.g. STROBEL et al 2012; YEŞILAYER & GENÇ, 2013; OZ & DIKEL, 2015; GULLER et al. 2017). Excessive amounts of n-6 (PUFA) and a very high n-6/n-3 ratio, as is found in today's Western diets, promote the pathogenesis of many diseases, including cardiovascular disease, cancer, depression, inflammatory and autoimmune diseases, whereas increased levels of n-3 PUFA exert suppressive effects. Past research indicated that humans evolved on a diet with n-6/n-3 ratio of approximately 1:1. Indeed, it seems that a ratio between 1:1 and 5:1 is beneficial to human health (SIMOPOULOS, 2002; STROBEL et al. 2012; HUSTED & BOUZINOVA 2016; ZÁRATE et al. 2017). Therefore, considering the obtained results herein, and despite of the higher amounts of arachidonic acid and docosahexaenoic acid- which are essential fatty acids for mammals- found in wild brown trout, the farmed brown trout is the one that n-6/n-3 ratio is most beneficial to human health according n-6/n-3 criteria (n-6/n-3 ratio closer to 1:1). Rainbow trout had the highest n-6/n-3 ratio (around 5:1). However, the dominant fatty acids were the n-6 linoleic acid, whereas the concentrations arachidonic and docosahexaenoic acids were very low when compared with farmed and wild brown trout. Differences reported between rainbow trout and farmed brown trout can be explained by differences concerning the aquaculture feed. According to STROBEL et al. (2012), the usage of n-6 PUFA-rich vegetable oils as an increasing alternative to fish oil in aquaculture feed. Therefore, is plausible to hypothesize that the diet of farmed brown trout was richer in fish oils, whereas rainbow trout diet was richer in vegetable oils.

The most represented age range of the consumer panel was from 22 to 29 years old, representing 43% of all consumers. Only 1.69% of consumers were older than 50. The majority of consumers who participated in this test were male. The pattern of fish consumption was about once or twice a week. The composition of fish body are commonly considered to influence fish sensory variables such as taste, texture and appearance, which, in turn, determine fish quality, consumer acceptance and commercialization (POHAR, 2011; OKEN et al., 2012; CLARET et al., 2014). Despite the differences in the composition, all samples were well accepted by consumers' panel. However, in the present research, farmed brown trout and rainbow trout had higher "taste" and "appearance" ranks than the wild trout (Table 3). POHAR (2011) also verified that consumers had a slight preference by farmed brown trout. However, for other fish species, WEBSTER et al. (1993) and GRIGORAKIS et al. (2003) reported that the panel of consumers surveyed clearly preferred wild to farmed fish. In the case of rainbow trout OZEGUL et al. (2013) also reported that wild trout was preferred by the consumer panel. Differences in fatty acid content may have influenced some sensory properties and were reflected in the observed slight differences in the scores attributed (RASMUSSEN, 2001; SUOMELA, et al., 2016). In future, since the present study focused on a sample of young consumers, it would be necessary to create consumers' panels with more diversified ages and socio-economic characteristics in order to evaluate if sensory variables have any influence on the preference of the fish origin.

CONCLUSION

The present study although preliminary, provided valuable information concerning the fatty acid compositions of wild and farmed trout. Despite of both, farmed and wild fish, comprised principally mono and polyunsaturated fatty acids, wild brown trout presented higher amounts of docosahexaenoicacid, α-linolenic acid Eicosapentaenoic acid and Arachidonic acid. These unsaturated fatty acids – mainlyarachidonic acid and docosahexaenoic acid, which are essential fatty acids-are considered most beneficial for human health and were more abundant in wild trout fillets. However, as many river ecosystems and the associated biodiversity are strongly threatened (e.g. DUDGEON et al., 2016),

Table 3 - Comparison of the sensory variables evaluated by the consumers' panel (Mean± SD and significance).

Sensory variables	brown trout (farmed)	brown trout (wild)	rainbow trout (farmed)	Significance
Appearance	7.37±2.21	6.91±2.20	7.74±1.83	NS
Taste	7.27±2.21	6.88±2.41	7.21±2.26	NS
Texture	7.11±2.31	7.35±2.06	7.41±2.21	NS
Global appreciation	7.10±2.26	7.25±2.07	7.41±2.06	NS

*Significant to P<0.05 and ***significant to P<0.001; NS not significant.

in the future, it will be necessary to promote the consumption farmed trout, whose composition in fatty acids can be manipulated through the improvement of commercial diets (REGOST et al., 2001; TURCHINI G.M. et al., 2005, ARSLAN et al., 2012, SOUMELA et al., 2016). According to STROBEL et al (2012) avoiding decrease in the nutritional value of farmed fish and improve n-6/n-3 ratio, strategies to ensure alternative n-3 PUFA sources in aquaculture feed need to be developed (e.g. transgenic microalgae and plants with high n-3 PUFA contents). Besides, more research is need to better understand the fatty acid dynamics of wild brown trout populations as well as the consumer and market preferences.

DECLARATION OF CONFLICTING OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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