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QUALITY ASSESSMENT OF TRADITIONAL SMOKED ARCTIC CHAR, *Salvelinus alpinus* (Linnaeus, 1758)

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Abstract

Regular consumption of fish can contribute to a more balanced and healthy diet. Incorporating fish into one`s diet is important for maintaining a healthy and sustainable lifestyle. The processes of traditional smoking undergo a complex series of steps that significantly influence its quality, nutritional composition, and sensory characteristics. To address this issue, a study was conducted to evaluate the meat quality and salt concentration of traditionally smoked Arctic char at different stages of the smoking process (fresh meat, salted meat, desalted meat, and smoked meat). All the physicochemical measured parameters varied significantly during the smoking processes, with the quality of the products remaining high. The final product, traditionally smoked trout, experiences a substantial decrease in water content through drying, salting, desalting, and smoking at high temperatures, increasing dry matter content. Furthermore, there is a significant boost in protein content in smoked trout compared to fresh, salted, and desalted meat.

***Key words**: human health, salmonids, smoked trout, traditional smoking.*

INTRODUCTION

Global fish consumption has steadily increased in recent years mainly due to its nutritional and health benefits (Chen et al., 2022; Hei, 2020). Regular consumption of fish can contribute to a more balanced and healthy diet (Pieniak et al., 2010; Swanson et al., 2012; Utri-Khodadady and Głąbska, 2023), offering various health benefits and reducing the risk of chronic diseases (Karimi et al., 2020; Zhao et al., 2016). Approximately 50% of the seafood humans consume consists of fresh and live fish. The term "fresh" refers to fish that have not undergone the freezing process, including still-alive fish, as well as those kept in the cold (but not frozen) or those packed in a modified atmosphere (McManus et al., 2014).

Usually, the common preservation methods used for fish products to extend their shelf life maintain quality, and ensure consumer safety are cooling and refrigeration, drying and dehydration, use of different types of packaging, salting, and use of different types of preservatives (Mahmud et al., 2018).

Besides the usual consumer choice of either fresh or chilled/frozen fish, other forms as smoked, sun-dried, brined, and canned fish products (in oil, water, or sauces), occupy a significant place in the market and are seen as valued delicacies. When it comes to fish and seafood products, consumer safety is of major importance due to the potential risks associated with microbial, chemical, and biotoxin contamination (Biji et al., 2016; Mohanty et al., 2019; Novoslavskijv et al., 2015). Ensuring the safety of fish products involves a combination of good manufacturing practices and regulatory oversight (Hidayat et al., 2019).

The crafting of traditional smoked trout is a particularly meticulous process that involves the careful selection of fish specimens and ingredients, followed by different cleaning methods, brining (immersing fish in a salt solution), and hot smoking (70-85°C) to enhance flavor, texture, and preserve its freshness over time (Belichovska et al., 2019). The processes of traditional smoking undergo a complex series of steps that significantly influence its quality attributes, nutritional composition, and sensory characteristics (Belichovska et al., 2019, Sava et al., 2020). Each step in the production process contributes to the unique characteristics that make smoked trout a cherished food item among consumers.

The majority of research conducted on smoked meat focuses solely on the end product. There is limited analysis of the particular steps involved in the production process. Thus, this study approaches the quality assessment of smoked meat of Arctic char, *Salvelinus alpinus* (Linnaeus, 1758) species in each step of the traditional way of smoking (fresh, salted, desalted, and smoked meat). The main objective was to determine the physico-chemical properties of traditional smoked trout meat, and an analysis of the salt content used in the smoking process.

MATERIALS AND METHODS

All procedures involving animals were conducted following Romanian and European Legislation (Law no. 43/2014; EC-Directive 2010/63/EU). The Animal Ethics Committee of the UASVM Cluj-Napoca approval (No. 145/2019) was obtained before the study started and followed all the bioethical rules and guidelines applicable to animal studies described by them.

Fish and Experimental Protocol

The fish specimens used in this study were sampled from a trout farm located in Râșnov, Brașov County, named Trecătoarea Ursului. One hundred specimens of Arctic char were used in the study, with an average weight of 251.3 ± 0.63 g, and an average total length of 28.5 ± 0.68 cm. The specimens used in the study were clinically healthy.

The traditional smoking stages were: harvesting, stunning (mechanical stunning percussion in the dorsal-aboral region of the head), evisceration (removing of the internal organs), washing (removal of mucositides and impurities adhering to the fish surface, elimination of blood and viscera), salting (prepare a curing mixture using salt and water, salting time is at least 16 hours, under refrigeration conditions, 2-4°C) desalting (washing), drying (the washed fish is left to dry, between 2 and 4 hours), hot smoking at 70-85°C (the fuel used for smoking is made of beech and cherry wood, stifled when necessary, with nettle and fir satin), followed by cooling and resting phase (the fish needs to cool to room temperature before refrigerating) (Sava et al., 2020; Sava et al., 2023).

Physicochemical Analysis

Five samples from different places in the smoking chamber were taken and analysed during the different smoking stages. Samples were examined as fresh, salted, desalted, and smoked meat. Moisture content was determined by the reference method SR ISO 1442:2010. The dry matter content was determined according to Mertens et al., 2004. Fat content was determined by the Soxhlet method based on the reference method SR ISO 1444:2008. The total nitrogen content was determined by the Kjeldahl method based on the reference method SR ISO 937:2007, with the subsequent calculation of the protein content. The non-nitrogenous extractive substances (SEN) content was determined by the standard method, according to Odagiu and Porca, 2003, and the ash content according to the method used by Perez and Andujar (1981).

Data analysis

The following fish meat parameters were measured in percentages: moisture, dry matter, fat, protein, non-nitrogenous extractive substances (SEN), ash, and supplemented salt. Stages of meat preparation were defined as treatments with the following steps: 1_fresh (the non-treated fish meat), 2_salted, 3_desalted, and 4_smoked. We compared fish meat parameters between treatments with the help of a paired t-test or with the Wilcoxon test in case data was not normally distributed (just the case of ash percentage in fresh samples).

To place the nutritional values of *S. alpinus* after this traditional processing methodology in the context of a wider fish meat palette available on the market, we compared the data from our study with values obtained in another study of our research team, written by Sava et al. in 2020, in a similar study from two other species: *Salvelinus fontinalis* (Mitchill, 1814) and *Oncorhynchus mykiss* (Walbaum, 1792).

We compared our data to the data obtained in the Sava et al. 2020 study with the help of a one-way ANOVA or a Kruskal-Wallis test, depending on the data distribution. Normal distributions of all parameters were checked with a Shapiro-Wilk test. All statistical analyses and graphs were performed in the program RStudio (Posit team, 2023). We assembled graphs in the form of Boxplots that represent median values (line inside the box), interquartile interval (box), minimum and maximum values (whiskers), and outliers (circles). Letters above or under parameter values express differences from pairwise t-tests or Wilcoxon test comparisons. Different letters between treatments represent significant differences at the $P<0.05$ threshold.

RESULTS AND DISCUSSIONS

Moisture varied significantly with treatment: through salting the moisture percentage sank significantly from 72% to 70%, followed by an increase to approximately fresh levels in the desalting stage, and then dropping to approximately 62% after smoking (Tab. 1, 2, Fig. 1).

Dry matter followed a complementary pattern to moisture, significantly varying between treatments. Dry matter increased through salting, decreased after desalting to approximately fresh levels, and increased again by approximately 10% after smoking (Tables 1, 2, Figure 1).

Fat percentage was lowered by one percent after salting, however, the percentage returned to a similar value of the fresh meat after smoking (Tables 1, 2, Figure 1).

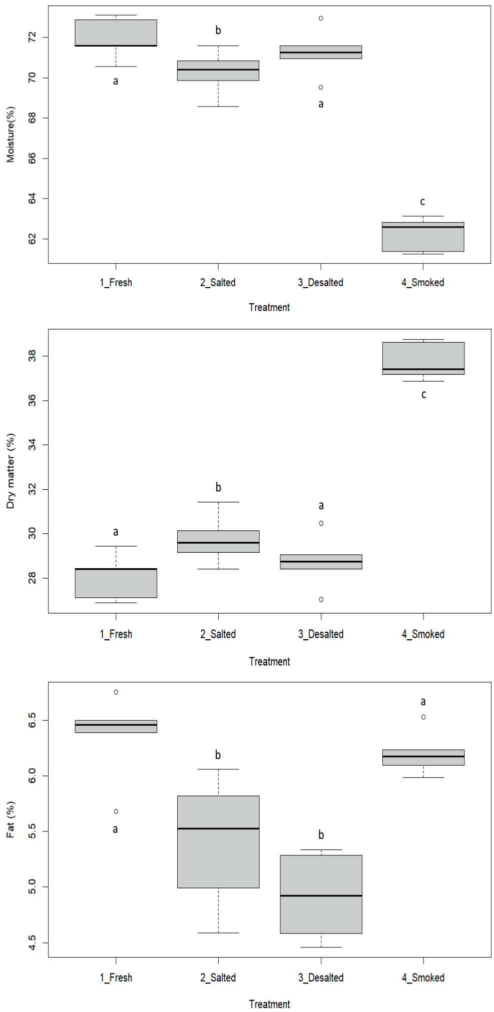

Figure 1. Percentages of moisture, dry matter, and fat measured in samples of *S. alpinus* meat in different stages of processing (treatments)

Table 1. Mean and Standard Deviation values for measured parameters of *S. alpinus* meat samples in different stages of processing (treatments)

Parameter	Treatment	Mean	Standard deviation
Moisture % (N=5)	Fresh meat	71.94	1.05
	Salted meat	70.26	1.13
	Desalted meat	71.26	1.23
	Smoked meat	62.23	0.86
Dry matter % (N=5)	Fresh meat	28.06	1.05
	Salted meat	29.74	1.13
	Desalted meat	28.74	1.23
	Smoked meat	37.77	0.86
Fat % (N=5)	Fresh meat	6.36	0.40
	Salted meat	5.40	0.60
	Desalted meat	4.92	0.40
	Smoked meat	6.20	0.20
Protein % (N=5)	Fresh meat	16.93	0.68
	Salted meat	15.43	0.73
	Desalted meat	16.79	0.80
	Smoked meat	22.06	0.65
SEN % (N=5)	Fresh meat	0.28	0.08
	Salted meat	0.24	0.02
	Desalted meat	0.43	0.07
	Smoked meat	4.10	0.52
Ash % (N=5)	Fresh meat	4.49	0.30
	Salted meat	8.67	0.55
	Desalted meat	6.60	0.58
	Smoked meat	5.41	0.32
Salt % (N=5)	Salted meat	3.77	0.42
	Desalted meat	1.93	0.10
	Smoked meat	1.12	0.19

Table 2. Pairwise comparisons with paired t-tests or Wilcoxon-test (df = 4 in all comparisons) of parameter mean values in successive stages of processing (treatments)

Parameter	F vs Sl	F vs D	F vs Sm	Sl vs D	Sl vs Sm	D vs Sm
Moisture %	t = 2.88 P = 0.045	t = 1.16 P = 0.310	t = 13.29 P < 0.001	t = -9.63 P < 0.001	t = 20.18 P < 0.001	t = 20.97 P < 0.001
Dry matter %	t = -2.88 P = 0.045	t = -1.16 P = 0.310	t = -13.29 P < 0.001	t = 9.63 P < 0.001	t = -20.18 P < 0.001	t = -20.97 P < 0.001
Fat %	t = 6.05 P = 0.004	t = 5.12 P = 0.007	t = 0.69 P = 0.530	t = 1.21 P = 0.294	t = -2.85 P = 0.046	t = -5.99 P = 0.004
Protein %	t = 4.06 P = 0.015	t = 0.29 P = 0.787	t = -9.33 P < 0.001	t = -2.83 P = 0.047	t = -18.07 P < 0.001	t = -13.22 P < 0.001
SEN %	t = 0.95 P = 0.397	t = -3.19 P = 0.033	t = -14.83 P < 0.001	t = -5.62 P = 0.005	t = -16.49 P < 0.001	t = -17.04 P < 0.001
Ash %	W = 0 P = 0.008	W = 0 P = 0.008	W = 1.00 P = 0.016	t = 41.35 P < 0.001	t = 10.55 P < 0.001	t = 3.75 P = 0.020
Salt %	-	-	-	t = 12.15 P < 0.001	t = 23.76 P < 0.001	t = 15.99 P < 0.001

*Significant differences are marked with a grey background. (F – fresh; Sl – salted; D – desalted; Sm – smoked)

Protein percentage was lowered after salting, but increased back to fresh levels after desalting and increased significantly by 5% after smoking (Tables 1, 2, Figure 2).

Non-nitrogenous extractive substances (SEN) did not differ between fresh meat and salted meat; however, after desalting, the percentage of SEN was higher and increased even more in smoked samples of fish meat.

Ash percentage increased significantly after salting; however, ash percentage was lowered after desalting, and got even lower after smoking to approximately 1% higher than in the fresh samples.

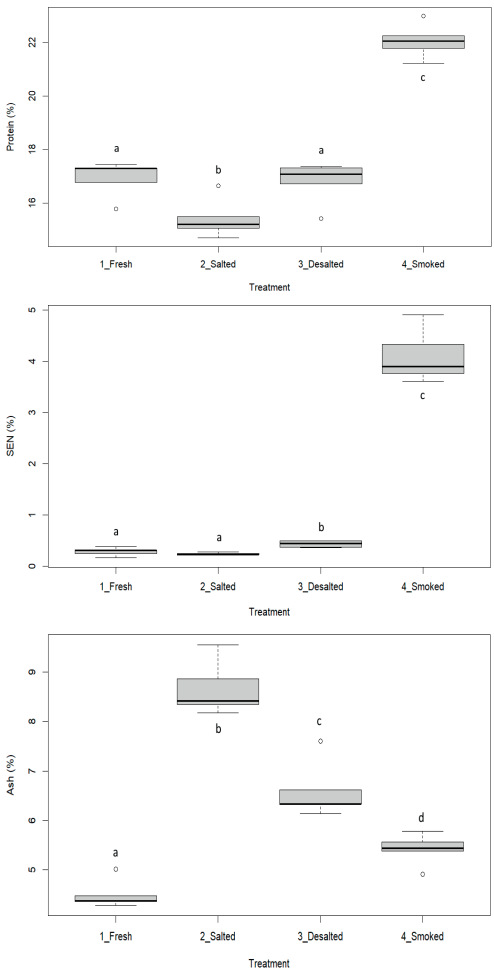

Figure 2. Percentages of protein, non-nitrogenous extractive substances, and ash measured in samples of *S. alpinus* meat in different stages of processing (treatments)

For the supplemented salt percentage, we also recorded significant differences between treatments. After salting, the salt content was high in the samples, with a mean of 3.7%. After desalting and smoking, the salt percentage went down to a mean of 1.1% (Tables 1, 2, Figure 3).

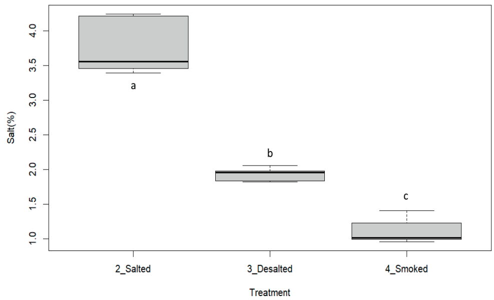

Figure 3. Percentages of salt measured in samples of *S. alpinus* meat in different stages of processing (treatments)

When comparing species' parameters, we observed significant differences for the following parameters: Fat % (df = 2, F = 24.91, P < 0.001), Protein % (df = 2, F = 5.07, P = 0.025), SEN % (df = 2, F = 11.65, P = 0.02), Ash % (df = 2, F = 138.60, P < 0.001). *S. alpinus* had higher fat and protein percentages than *O. mykiss*, but similar percentages to that of *S. fontinalis*. SEN percentage was lower in *S. alpinus* than in both other species. Ash percentage was higher in *S. alpinus* than in both other species. All mean values of the measured parameters in all three species are presented in Figure 4.

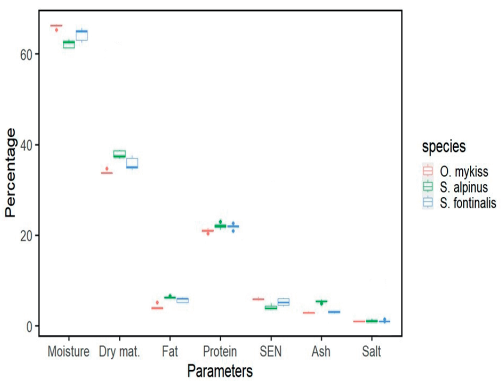

Figure 4. Mean values of measured parameters (in %) in *S. alpinus* compared to two other species, *S. fontinalis* and *O. mykiss*

CONCLUSIONS

During the traditional smoking process, the trout undergoes several stages that lead to significant changes in its chemical composition. The trout is first washed, salted, then desalted, and finally, it is dried and smoked at high temperatures. As a result of this process, the trout loses a substantial amount of water content, which increases its dry matter. Additionally, the protein content of smoked trout is significantly higher than that of fresh, salted, and desalted fish due to changes in the amino acid structure that occur during the hot-smoking process.

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