No. 130/24, 37–48
ISSN 2657-6988 (online)
ISSN 2657-5841 (printed)
DOI: 10.26408/130.03

Submitted: 24.11.2023
Accepted: 22.04.2024
Published: 28.06.2024

QUALITY MATTERS: ANALYSING THE IMPACT OF COOKING TECHNIQUES ON SELECTED PROPERTIES OF SALMONIDS

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Abstract: This paper explores the three cooking methods (frying, grilling, and steaming) related to fish most commonly utilized by consumers, with a focus on their implications for both food quality and safety. The mean contents of water and fat were found to be 12.63% and 66.22%, respectively. The fat content of the raw fish samples was significantly lower than that of heat-treated samples, and the percentage fat content did not differ significantly between treatment types. In trout, the greatest water loss was observed during grilling and steaming; in the case of salmon, during frying and steaming. In raw trout and salmon, 5.56 log cfu/g of psychrotrophic bacteria and 5.20 log cfu/g of psychrotrophic bacteria were found, respectively. The steaming method proved the least efficient at eliminating psychrotrophic bacteria. In the present study, the grilling method was found to be the best for quality, safety and better health.

Keywords: cooking methods, food quality, microbial safety, rainbow trout, salmon.

1. INTRODUCTION

Salmonid fish of the following species have long been farmed in Poland: rainbow trout (*Oncorhynchus mykiss*), spring trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta morpha fario*), bull trout (*Salmo trutta morpha trutta*), and Atlantic salmon (*Salmo salar*) (ar). In recent years, the consumption of fish and seafood per person in Poland has increased from 12.92 kg in 2017 to 13.33 kg in 2020 [Wysoczyńska 2021]. According to the literature, an average serving of 100 g of fish provides more than 50% of the recommended daily protein intake, between 10 and 20% of minerals, and a significant proportion of vitamins.

It is also recommended that fish be considered a mandatory part of the diet, as it offers a number of health benefits, including a reduction in the risk of coronary cardiovascular disease and the incidence of inflammatory diseases [Marimuthu et al. 2012; Khalili Tilami and Sampels 2018; Mahmood and Sabow 2020].

The most commonly used methods of culinary processing of fish are frying, roasting, and steaming.

The parameters used in these processes, i.e., the heating temperature and processing time, have a significant influence on the meat properties. Heat treatment may lead to lipid oxidation, affecting meat quality [Abraha et al. 2018; Hernández-Sánchez et al. 2020]. The cooking methods used enhance the aroma and flavour, improve digestibility, and inactivate pathogenic microorganisms [El-Lahamy et al. 2019].

The processing methods, in particular the type of heat transfer (e.g., heat transfer by a liquid during convection), have a significant influence on the quality and structure of a foodstuff [Nawaz et al. 2021]. Animal products (such as meat and fish) are more susceptible to harmful microorganisms and should be cooked thoroughly before consumption. Nutrient losses vary depending on the heat treatment method, and undesirable microorganisms in the treated product are eliminated at temperatures above 70°C.

The aim of this study was to evaluate the effects of frying, grilling, and steaming on selected quality parameters of salmonids.

2. MATERIAL AND METHODS

2.1. Description of the test material

The test material consisted of fresh fillets of Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) purchased from local fish shops in Puck (Pomorskie Voivodeship).

In the store, the products were stored in Styrofoam packaging filled with ice, under controlled temperature conditions of 0 to +2ºC. From the store to the microbiology laboratory, the fish were transported in this packaging, maintaining the continuity of the "cold chain of distribution." The transport time was about 45 minutes.

Immediately upon arrival at the laboratory, the samples were analysed. Each fillet was divided into equal parts (12.0 x 4.0 x 2.0 cm), one of which was a control sample, and the others were subjected to grilling, frying, and steaming (typical cooking methods conducted in households) (Fig. 1). The selection of pieces for heat treatment was random.

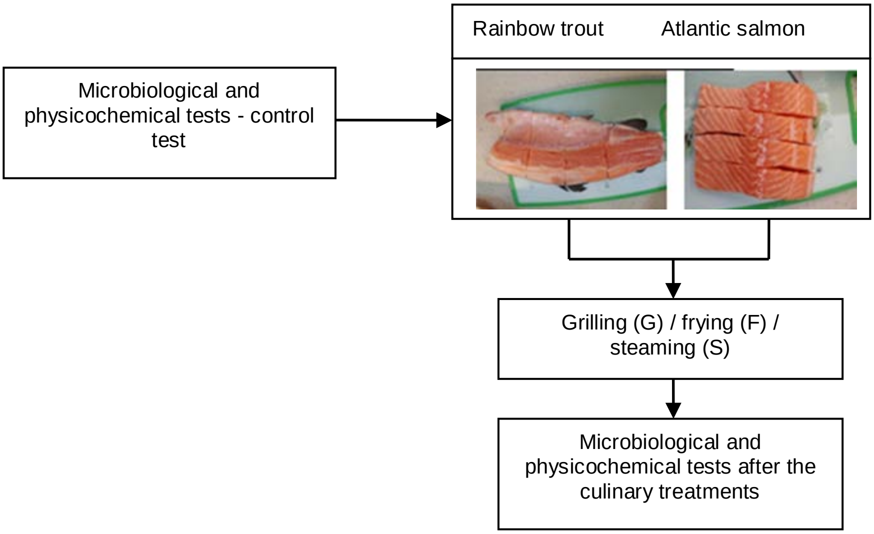

Fig. 1. Test diagram

Source: own study

2.2. Heat treatment of the test material

The test material was steamed (except control tests) on an OptiGrill +XL GC722G (Tefal, France), fried in a pan (Tefal, France), or steamed in an Vitacuisine Compact VS4003 steam cooker (Tefal, France). For processing on the electric grill and for cooking in the steam cooker, the process parameters were selected according to the recommendations of the equipment manufacturers. During frying, the process was conducted in a pan with some rapeseed oil until a temperature of 80 ±1°C (approx. 5 minutes) was reached in the thermal centre. During grilling and steaming, the internal temperatures of the fish were 80°C ±1.5°C and 75 ±1°C, respectively.

2.3. Microbiological analyses

A 20 g sample was aseptically obtained from the muscle of each fish and homogenized with 180 ml Ringer's liquid using a Stomacher Lab-Blender 400 (Seward, Worthing, UK). Progressive decimal dilutions were made and plated on plate count agar (PCA, Merck) for counts of psychrotrophic bacteria. The plates were incubated at 7°C for 10 days [Boulares, Mejri and Hassouna 2011].

The presence of *Salmonella* spp., *Listeria monocytogenes,* and *Vibrio parahaemolyticus* was determined in accordance with:

- *Salmonella* spp. as per PN-EN ISO 6579-1:2017-04;

- *Listeria monocytogenes*, as per PN-EN ISO 11290-2:2017-07;
- *Vibrio parahaemolyticus*, as per PN-ISO 8914:2002.

All assays were conducted after cooling (about 20 min) for the control sample and after each type of cooking treatment, in three independent repetitions.

2.4. Physical-chemical analyses

After the removal of material for microbiological analysis, the samples were crushed and 5 g weighed (to the nearest 0.01 g) for the analysis of the fat and water contents of the fish muscles, according to Krełowska-Kułas [1993].

The lipid content of the samples was determined by the Gerber method (butyrometric), which consisted of burning the meat in a fat meter with sulfuric acid (VI) and separating the fat from other substances by centrifugation.

The moisture content was determined by drying the sample in a dryer at 130°C to a constant mass and then determining the difference in weight before and after drying.

The temperature of the culinary fish meat was measured with a bayonet thermometer (TFADostmann Pocket-Digitemp, Germany). The probe was inserted into the thickest part of the fish, and then the temperature (in °C) was read off the display.

All assays were conducted after cooling (about 20 min) for the control sample and after each type of cooking treatment, in three independent repetitions.

2.5. Statistical analysis

Basic measures for location and variability were calculated. The conformity of the data to the normal distribution was evaluated using the Kruskal-Wallis test, the homogeneity of variances with Levene's test and the Mauchley's sphericity test was also performed. The significance of differences between the groups was estimated on the basis of the monofactorial ANOVA model with repeated measurements. For the multi-group comparisons, the Newman-Keulus test and contrast analysis were used.

The relationship between log 10 of the total number of psychrotrophic microorganisms (cfu/g+1) is shown in the graph. Finally, a straight correlation coefficient was calculated.

3. RESULTS

3.1. Results of the physico-chemical analyses

The fat content of the salmon samples (C+G+F+S) was significantly higher than that of the trout samples (C+G+F+S) (average: 22.88 ±3.929% vs. 9.90 ±4.421%) ($F = 147.10$; $p < 0.0001$; $\eta^2_{part} = 0.94$). The fat content of the raw fish samples was significantly lower than that of heat-treated samples, and the percentage fat content did not differ significantly between treatment types (Tab. 1).

Table 1. Fat content [%] depending on the heat treatment method, including both salmon and trout ($F = 8, 0.99$; $p = 0.0002$; partial $\eta^2 = 0.47$)*

Heat treatment	M [%]	SD	-95% PU	+95% PU	Min.	Max.
Control (C)	12.63^{abc}	8.762	11.40	13.85	3.00	24.00
Grilling (G)	16.42^{a}	6.708	14.40	18.43	5.00	24.00
Frying (F)	16.96^{b}	6.930	15.03	18.89	7.00	28.00
Steaming (S)	19.54^{c}	7.777	16.40	22.69	9.00	32.00

*Analysis of individual heat treatment (C, G, F, S) results combining both fish species.
Averages denoted by the letters a and b differed at $p < 0.01$ and those denoted by c at $p < 0.001$;
PU – confidence level, M – mean, SD – standard deviation.

Source: own study.

The interaction between the sampled fish species and their treatment was not statistically significant ($F = 1.47$; $p = 0.2437$; $\eta^2_{part} = 0.13$). The lowest fat content was found for the raw samples of both species (salmon 20.85 ±2.229% and trout 4.42 ±1.497%). After heat treatment (regardless of the variant), a statistically significant increase from 22.17% was observed for the grilled salmon samples to 25.50% for the steamed salmon samples, whereas for the trout, the grilled and steamed samples contained 10.67% and 13.58% fat, respectively.

The analysis of the contrasts showed that the differences in fat content [%] between samples that underwent conservation were significant for both salmon and trout ($F = 7.20$; $p = 0.0230$) (Fig. 2).

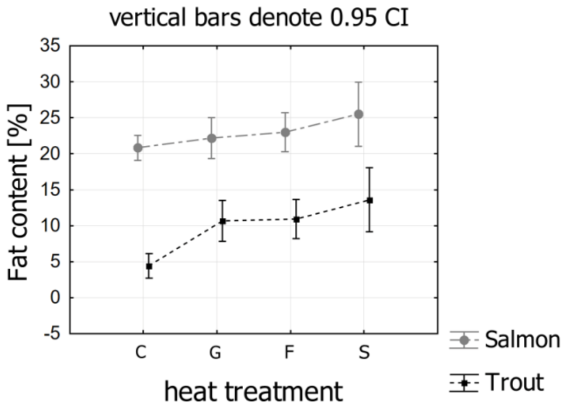

Fig. 2. Change in average fat content according to fish species and applied heat treatment method, CI – confidence intervals

Source: own study.

In general, trout had a significantly higher water content than salmon (Tab. 2).

Table 2. Water content [%] depending on fish species

Species	M	SD	-95% PU	+95% PU	Min.	Max.	N
Salmon	52.27	5.745	50.54	53.99	41.53	62.97	24
Trout	65.27	5.314	63.55	67.00	58.18	75.76	24

N – number of samples, PU – confidence level, M – mean, SD – standard deviation.

Source: own study.

The highest average water content was present in the test samples before heat treatment. The average water content of the raw samples was 66.22 ± 7.312%, which differed statistically significantly from the average water content of the heat-treated samples (a decrease by about 10%). The interaction between the species sampled and the mode of preservation was statistically significant ($F = 6.13$; $p = 0.0022$; $\eta^2_{part} = 0.38$). The treatment affected the water content [%] in the muscles of the fish. The water content was highest in raw samples from both fish species (72.78 ±2.821% trout vs. 59.66 ±2.546% salmon). In trout, the greatest water loss was observed during grilling and steaming; in the case of salmon, during frying and steaming (Fig. 3).

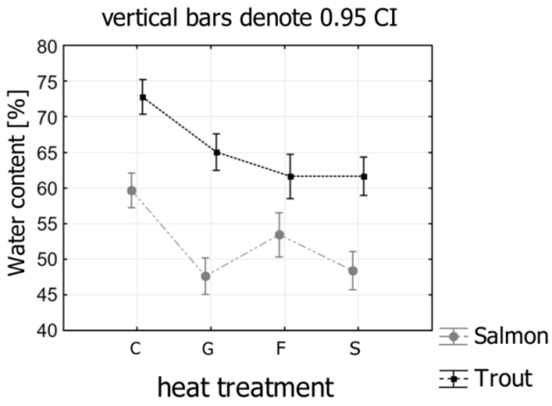

Fig. 3. Change in average water content according to fish species and applied heat treatment method

Source: own study.

There were no statistically significant differences between the water content of fried and steamed salmon (47.60% and 48.38%) or grilled and steamed trout (61.61% and 61.66%).

3.2. Results of microbiological analyses

There were no statistically significant differences in the mean number of psychrotrophic microorganisms [log cfu/g] by fish species ($F = 4.97$; $p = 0.0897$; $\eta^2_{part} = 0.55$).

The method of thermal treatment applied did not significantly differentiate the $\log_{10}$ of bacterial count; however, subjecting samples to one of the three forms of thermal treatment (G, F or S) significantly reduced the occurrence of bacteria.

Compared to the fried, grilled, or steamed samples, the average number of psychrotrophic bacteria was statistically significantly higher in the raw samples (Fig. 4).

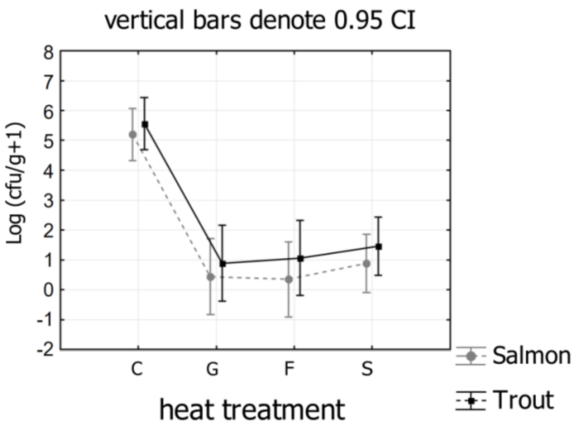

Fig. 4. Change in the average number of psychrotrophic microorganisms [log cfu/g] according to fish species and preservation method

Source: own study.

There was no statistically significant association between preservation temperature (G+F+S) and log of the number of psychrotrophic microorganisms (Fig. 5).

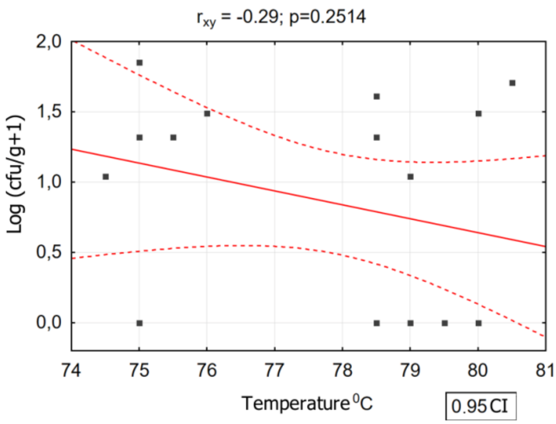

Fig. 5. Association between preservation temperature and log of the number of psychrotrophic microorganisms

Source: own study.

Salmonella spp., *L. monocytogenes*, and *V. parahaemolyticus* were detected in about half of the samples of the raw (control) fish test samples. After the applied cooking treatments, these bacteria were no longer observed in the fish. There was no statistically significant association between fish species and the presence of *Salmonella* spp., *L. monocytogenes*, or *V. parahaemolyticus* ($p > 0.05$).

4. DISCUSSION

Fish muscle consists of an average of 70% water. In fatty fish, the water content is about 65%, and in lean fish about 80% [Pal et al. 2016]. In the salmonids we studied, which qualify as fatty fish [Taşbozan and Gökçe 2017], the average water content was 66.2%. Similarly, El-Lahamy et al. [2019] found that the average water content of raw fish samples was statistically significantly different ($p < 0.05$) from that of heat-treated samples (water content decrease of about 10%). Denaturation of proteins during cooking causes evaporation of water molecules, resulting in a decrease in the proportion of water in the protein structures [Hernández-Sánchez et al. 2020].

Wang et al. [2020] pointed out that the water storage capacity of the fish continuously decreased during the steaming process, and losses during cooking increased. Hernández-Sánchez et al. [2020] found a reduction in the total water content during heat treatment of tilapia samples, with the exception of fish steamed at 60°C. In our own studies, water losses were observed in salmon and trout after all thermal processes (Fig. 3), similar to the data of El-Lahamy et al. [2019] and Oduro, Choi and Ryu [2011]. The results suggest that fish that has undergone a cooking treatment may be more durable due to the lower moisture content [Hernández-Sánchez et al. 2020]. When the water content of a fish drops below 25% of its net weight, the growth intensity of the bacteria decreases [Pal et al. 2016]. In raw trout and salmon, 5.56 log cfu/g of psychrotrophic bacteria and 5.20 log cfu/g of psychrotrophic bacteria were found, respectively (Fig. 4).

Eizenberga et al. [2015] found a psychrotrophic bacteria concentration of 5.50–6.91 log cfu/g on the surface (skin) of the investigated fish. The presence of psychrotrophic bacteria in fish may be due to the pollution of their environment, the processing method, the level of hygiene among workers, and the use of contaminated water during transport. These bacteria are responsible for the spoilage of various chilled foods, especially fish, and may pose a risk of food poisoning [Salem, Osman and Shehata 2018]. Grilling and frying reduced the number of psychrotrophic bacteria by about 4.7 log cfu/g and steaming by 4.2 log cfu/g (Fig. 4).

However, the bacteria remaining in the salmonids studied can multiply under favourable conditions (e.g., more than 2 hours at room temperature) and make the fish unsafe for consumption.

The results of our own studies show that the greatest reduction in bacteria was observed during deep frying, which is consistent with the observations of El-Lahamy et al. [2019]. The results of a study by Skałecki et al. [2013] showed that the average moisture content of rainbow trout was 74.5%, and the average lipid content was 4.5%. Białas et al. [2011] found that the fat content of Norwegian salmon was 13.2%, while Łuczyńska, Tońska and Borejszo [2011] found that salmon and rainbow trout had a fat content of 11.6% and 4.4%, respectively. The lipid content of fish depends on a number of factors, including the aquatic environment (sea water, fresh water, cold, or heat), the biological characteristics of the environment, seasonal changes, sexual maturity, the species, and dietary habits [Taşbozan and Gökçe 2017].

The literature evidence shows that lipid concentrations increase regardless of the cooking method, because heat can extract lipids from the depths of fish muscle tissue, especially after partial water loss due to evaporation [Marimuthu et al. 2012; Hernández-Sánchez et al. 2020]. In our studies, the highest lipid content was reached by steaming (Fig. 2). A high percentage of fat in the muscle indicates a high energy value of the product, but from a nutritional point of view, excessive fat has a negative effect on the human body [Hadi and Moniem Elminshawi 2007].

In addition, the use of oil to fry fish may increase the risk of cardiovascular disease, which is why consumers are increasingly turning to non-oil-based methods, such as baking or microwave heating [Nawaz et al. 2021]. Lewandowska et al. [2017] found that the presence of *Vibrio* sp. in salmonids was at the level of 1.4% in 2015 and 2.2% in 2016. These bacteria are considered to be the main cause of gastroenteritis in humans [Pal et al. 2016]. The summary of study results prepared by Novoslavskij et al. [2016] shows that the presence of *Listeria monocytogenes* in Atlantic salmon was at the 8.6% level, and in cultured rainbow trout it was at 14.6%. *Salmonella* did not occur in either Atlantic salmon or rainbow trout, similar to those reported by Bainy et al. [2015].

In our own studies, *Salmonella* spp., *L. monocytogenes*, which may contaminate fish when they are caught, processed, or stored [Pal et al. 2016], and *V. parahaemolyticus* were detected in 50%, 33%, and 50% of raw salmonids, respectively. These pathogens were not detected after cooking, so the applied temperature and time parameters proved to be effective in eliminating these microorganisms.

In the future, it would be worthwhile expanding the study to include other fish species and incorporate additional thermal processing methods to obtain more comprehensive and representative results.

5. CONCLUSIONS

The findings highlight the effectiveness of cooking in reducing the presence of psychrotrophic bacteria and eliminating common bacterial pathogens, such as *Salmonella* spp., *L. monocytogenes*, and *V. parahaemolyticus*. Consumers should be encouraged to opt for oil-free cooking methods, such as grilling, which not only preserves the quality and nutritional value of the fish but also enhances safety. The immediate treatment of fish just before consumption emerges as an effective means to reduce or eliminate the risk of food poisoning, ensuring both quality and safety in every culinary experience.

6. ACKNOWLEDGEMENTS

The research was financed from the funds allocated to UMG departments for research activities under project number WZNJ/2024/PZ/01.

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