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SMOKING TEMPERATURE CHARACTERISTICS AND INFLUENCE OF QUALITY INDICATORS ON PHYTOPHAGUS FILLET (*Hypophthalmichthys molitrix)*

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Abstract

The evolution of modern technologies for preserving fish and fish products has led to the eclipse of the preservation properties of many traditional methods, including the smoking method. Nowadays, the main purpose of smoking has been redirected towards highlighting the sensory quality rather than its preserving effect. The main aim of this paper is to highlight the physicochemical, sensory, and color characteristics of smoked phytophagous fillets. To produce the necessary products, nine specimens of phytophagous (Hypophthalmichthys molitrix) were harvested from the fish farm "Piscicola Vlădeni, CC&C PES SRL" Iasi, which were processed and prepared in the Microproduction Workshops of the Iasi University for Life Sciences "Ion Ionescu de la Brad". Three different smoking methods were applied to the fillets resulting from the phytophagous processing; hot smoking, semi-hot smoking, and cold smoking. From a physicochemical point of view, in the case of the batch with hot smoking quantity, a lipid content of 1.76±0.024% was recorded, higher compared to the L2ASC (0.94±0.04%) and L3AR (0.86±0.024%) batches. As regards protein content, the highest value was also found in lot L1AC (22.2±0.083%), followed by lot L2ASC (22.18±0.02%), with the lowest value in lot L3AR (21.96±0.024%). The most appreciated fillets were those processed by heat treatment with semi-warm and warm smoking.

Key words*: perishability, phytophagus fillet, quality parameters, smoked fish.*

INTRODUCTION

The antimicrobial and antioxidant characteristics of smoke have been extensively studied over the years by various researchers in different countries of the world (Horner, 1997). Substances such as formaldehyde and phenols are released during the burning of wood, which gives the smoke preservative properties. Thanks to these substances, the smoking process inhibits the growth of many microorganisms and limits oxidative reactions (Abou-Taleb et al., 2011). Exposure of fish to smoke leads to a reduction in moisture levels and an enrichment of the fish meat with various substances in its composition. The preservation effect results from the consecutive or simultaneous action of several of the following factors: thermal inactivation of the product microflora, water activity, pH, antibacterial activity of the additives used before smoking, the concentration of antimicrobial and antioxidant components of smoke in the product, barrier properties of the packaging and storage temperature (Arvanitoyannis & Kotsanopoulos, 2012). Therefore, the high-quality shelf life and practical shelf life of different smoked foods vary from a few days at room temperature to several months at refrigeration temperatures, depending on the type, initial freshness, microbial contamination, and shape of the raw material, salting, and ripening parameters, water loss by dripping or drying, temperature, duration, and density of smoke in the smokehouse and packaging and storage conditions of the product.

Depending on the temperature of the smoking chamber, smoking can be cold, semi-hot, or hot. In the case of cold smoking, the temperature in the smoking chamber must not exceed 40°C. Cold-smoked fish is a product of the complex action of the salt (NaCl), smoke components, dehydration, and proteolytic and lipolytic enzymes (Hakimeh et al., 2010). Cold-smoked fish has a delicate smoky aroma and a longer

shelf life than hot-smoked fish because it contains significantly less water and more salt. In the case of semi-hot smoking, the temperature ranges from 40 to 80°C.
The proteins in the fish are partially denatured and the enzymes are completely inactivated.
For hot smoking (boiling), the temperature varies between 80 and 170°C. The fish proteins are completely denatured and the enzymes are inactivated. The product has a low salinity and high water content, is lightly smoked, soft, and juicy, has a slightly smoky aroma, and cannot be stored for a long time (Puke et al., 2020).
As such, the main objective of this work was to highlight the applicability of differentiated smoking parameters (hot smoking, semi-hot smoking, and cold smoking) to obtain fish dishes with a pleasant sensory appearance and well-defined shelf-life characteristics (Másílko et al., 2015).

MATERIALS AND METHODS

The current work was carried out in the Food Technologies Department of IULS Iasi, the research activity being carried out in the Meat Processing Workshop, the Meat and Meat Products Technology Laboratory, and the Sensory Analysis Laboratory.
The necessary raw material, phytophagous (*Hypophthalmichthys molitrix*), was purchased from the fish farm "Piscicola Vlădeni, CC&C PES SRL" in Iasi County.
The experiment included the production of three batches of smoked phytophagus by three different smoking methods including different parameters of the applied heat treatment. The smoking methods applied are described in Table 1. The harvested phytophagous was transported under refrigerated conditions to the Meat Processing and Processing Plant, and operations including deboning, gutting, heading, and filleting were carried out. The resulting fillets were divided into three equal batches and salted at a rate of 1.2% of the quantity of raw material, applying the salting method by manual kneading so as not to detach the muscle tissue from the skin and to keep the fillets intact. The salted fillets underwent a dry maturation period under refreezing conditions at 2-4°C for 12 hours.

Table 1. Smoking heat treatment

Lot code	L1AC		L2ASC			L3AR	
Parameter	*Drying*	*Smoking*	*Drying*	*Smoking I*	*Smoking II*	*Drying*	*Smoking*
Time (min/h)	30	30	30	30	120	2	8
Temperature inside the cell (°C)	60	110	16	20	80	16	26
Temperature in the thermal centre (°C)	50	86	12	16	69	12	20
Humidity (%)	40	40	40	40	40	40	40

Raw chemical determinations applied to examine the shelf life of the fillets included quantitative analysis of moisture content, amount of protein remaining after smoking, collagen, fat content, and salt concentration using a versatile near-infrared (NIR) spectroscopic determination method using the Food Check meat analyzer (Bruins Instruments, no. 21F7122065). Physical determinations involved pH analysis using a digital meat pH meter and determination of brightness (L*) and red (a*) and yellow (b*) color indices of the finished product (smoked phytophagous fillets) in the CIELAB system using the Konica Minolta Chroma Meter CR-410 color analyzer.
The sensory analysis was carried out in the Sensory Analysis Laboratory of IULS Iasi in a single tasting session with a panel of 18 tasters. The tasters were represented by second-year students of the same university, of the food engineering profile. The three samples were identified with codes consisting of numbers and sample abbreviations and the fillets were portioned into finger-thick sticks so that the sample contained a part of the anatomical region from the belly and apart from the backbone, for the most accurate evaluation.
A descriptive CATA (Check-All-That-All) method was used to determine the sensory analysis and the samples analyzed with the most appealing appearance, the most uniform appearance, the most uniform color, the most intense color, the most intense smoke smell, the most intense non-specific smell, the most

intense fishy taste, the most intense smoke taste, the juiciest sample, and the driest sample were scored.

RESULTS AND DISCUSSIONS

The results obtained from the chemical analysis of smoked phytophagous fillets showed the effectiveness of the heat treatment on the shelf life and the nutritional value of the products resulting from the technological smoking process. From Table 2 it can be seen that the most perishable batch with a low shelf life is represented by the batch with hot smoking (L1AC) which presents the highest percentage of moisture remaining in the product with an average value of 76.76±0.024 %. The high percentage of moisture in this batch is due to the low heat exposure time of the product, which facilitated both the maintenance of a high percentage of protein (22.2±0.083%) and lipids (1.76±0.024%) in the finished product. The semi-warm smoked batch (L2ASC) contains a lower percentage of moisture (76.74±0.050%) than L1AC and high values of protein (22.18±0.02%) and collagen (20.66±0.04%). The batch with the highest shelf life is the cold smoke smoked batch (L3AR) as the moisture value in the product is the lowest (76±0. 044%) compared to the other two batches ($p<0.05$). The low moisture content of the last batch resulted in a concentration of salt in the finished product (3.5±0.044%), the p-value is significant ($p<0.0001$), but also in a decrease of lipid content (0.86±0.024%).

Table 2. Chemical composition of smoked phytophagous fillets

Sample code	Lipid (%)	Protein (%)	Collagen (%)	Humidity (%)	Salt (%)
L1AC	1.76±0.024	22.2±0.083	20.36±0.024	76.76±0.024	2.76±0.067
L2ASC	0.94±0.04	22.18±0.02	20.66±0.04	76.74±0.050	1.2±0.002
L3AR	0.86±0.024	21.96±0.024	20.68±0.02	76.00±0.044	3.5±0.044
p-value	0.000^{**}	0.002^{*}	0.000^{**}	0.010*	$<0.0001^{***}$

ANOVA Tukey test: ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

The pH value is closely related to the water activity (wa), and therefore to the moisture content of the finished product. Table 3. reports the averages of the pH values obtained from the 5 pH readings. As the concentration of water in the product decreases, its acidity increases, thus, we can see that the sample with the lowest moisture content, cold smoking, shows the lowest pH value, showing distinctive differences ($p<0.0001$) between the three batches of smoked fillets.

To determine the colour of the smoked phytophagous fillets, the sample brightness (L*), the complementary red-green colour coordinate (a*) and the complementary yellow-blue colour coordinate (b*) were analysed. Table 3 shows that the sample with the highest value of brightness is represented by the sample with warm smoking (L1AC) with a mean value of 54.02±2.38, which also shows the lowest value of red colouration (0.85±0.72), the sample with cold smoking (AR) shows a mean brightness (47.29±2.12) with a red colour value of 3.50±1.22 and the darkest sample is the semi-warm smoked sample (L2ASC) which has a low lightness with an average value of 39.67±1.44 and is the most pigmented sample with an average red colour coefficient of 11.04±1.16.

Table 3. Physical parameters of smoked phytophagous fillets

Sample code	pH-value	L (*) ±SD	a (*)±SD	b (*)±SD
AC	6.516±0.013	$54,02^{A} \pm 2,38$	$0,85^{B} \pm 0,72$	$22,49^{A} \pm 1,97$
ASC	6.2±0.016	$39,67^{B} \pm 1,44$	$11,04^{A} \pm 1,16$	$20,09^{A} \pm 1,58$
AR	5.894±0.017	$47,29^{A} \pm 2,12$	$3,50^{B} \pm 1,22$	$23,22^{A} \pm 1,05$
p-value	<0.0001	0.000^{***}	$<0.0001^{***}$	0.354^{ns}

ANOVA Tukey test: ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; A,B - The same superscript letter within the same column means there is no significant difference between any two means ($p>0.05$).

Since 10 colour readings were taken, 5 on the inner and 5 on the outer side of the fillet, the differences identified for the yellow-blue colour (b*) are insignificant ($p = 0.354$). For the

brightness parameter, the differences recorded between samples were distinctly significant (p=0.000), while the red-green colour coordinates showed highly significant differences (p<0.0001.).

The determination of the quality idea of the finished products was carried out by the CATA sensory analysis method using multiple factor analysis (MFA).

From Figure 1. it can be seen that the semi-warm smoking sample (L2ASC) comprises the most positive indices, presenting the most appealing overall appearance with the most uniform colour.

The overall appearance is closely related to the colour of the sample, which is due to the two smoking stages of the thermal process that helped to form a colour of the most intense red, typical of smoking at high temperatures.

The cold-smoked batch (L3AR), with three indices, was the sample with the lowest moisture content, the most intense smoky taste and the fishiest smell. The intense smoke taste is due to the long exposure time of the phytophagous fillets to the heat treatment which lasted for 10 hours.

The last three quality indexes were positioned towards the sample with hot smoking (L1AC), which due to the short time of heat treatment (1 hour) was perceived as the most intense fish taste and as the most succulent sample. The assessors described this sample as having a "non-specific odour", with no observations of a non-conforming odour recorded by them.

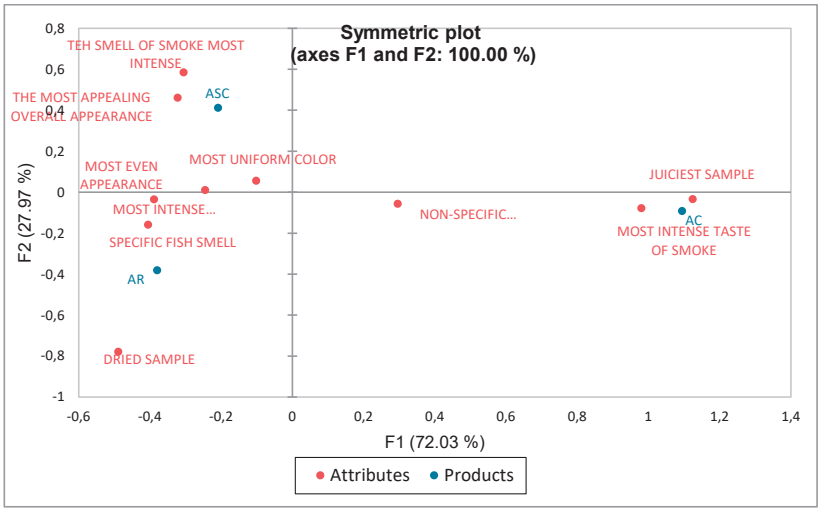

Figure1. Multiple factor analysis (MFA) of smoked phytophagous fillets assessed using the CATA test

CONCLUSIONS

Physico-chemical determinations showed that the hot-smoked batch (L1AC) has a high perishability, with the highest moisture content, but a high nutritional value, with the highest protein content. The chemical composition of semi-warm smoked phytophagous fillets (L2ASC) showed a high percentage of protein content, but had a lower moisture content compared to the hot smoked batch, thus increasing its shelf life. With the lowest moisture percentage and the driest sample, the cold-smoked batch (L3AR) has the highest shelf life. However, due to the long drying time, the protein percentage is low compared to the other two batches.

From a sensory point of view, the hot smoking batch (L2ASC) ranked last, thus the semi-warm smoking batch (L2ASC) ranked first in sensory determination, showing the most uniform appearance and color.

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