A novel process for obtaining smoke-flavoured salmon using water vapour permeable bags

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A B S T R A C T

We aimed to optimise a new smoking–salting method using water-vapour permeable bags to obtain smoke-flavoured salmon. This involved a smoking–salting process with three salt doses (4, 6, 8 g salt/100 g fresh salmon) and two packaging types: high barrier (HB) bags and water vapour permeable bags (WP) with different humidity levels (50%, 60% and 70% RH). The salting and vacuum packaging combination increased the salt concentration in the final product versus WP bag packaging. The lower the RH for WP-packed samples in the drying chamber, the lower the moisture and \( a_w \) values. The 8% salt dose/60% RH samples came closer to the \( a_w \) salt content and moisture levels determined in commercial samples. In WP samples, 50% and 60% RH completely evaporated the water released by muscle. Sensory attributes of the new product obtained similar scores to the commercial product. The new methodology is suitable to obtain smoke-flavoured salmon with similar physico-chemical characteristics and consumer acceptance to a commercial smoked salmon reducing processing steps and brine wastes.

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1. Introduction

Smoking is a preservation method that has been employed since ancient times. The preservative effect of smoking is due to a combination of different factors, including addition of salt, partial dehydration of tissues which occurs throughout the different stages of the process, and the preservative action of the smoke components. The smoking process slows down the biological processes and oxidative damage, and confers the final product sensory characteristics that consumers greatly appreciate.

The traditional smoking process involves different stages such as salting, drying and/or smoking. There is increasing interest in modifying the traditional smoking and salting processes according to industrial demands. Producers seek new methods to reduce processing times, minimise salt waste, reduce overall weight loss and/or improve the hygienic quality of the final product. Hence the salting step is especially critical. Currently, salting process improvements focus primarily on reducing processing times and using alternative techniques, such as direct brine injections (Thorarinsdottir et al., 2010), simultaneous salting–thawing (Barat et al., 2005) or vacuum impregnation (Chiralt et al., 2001).

A new salting process in which the exact amount of salt to be absorbed by the fish is directly dosed has been proposed by Fuentes et al. (2008). This procedure has been demonstrated capable of reducing waste and obtaining homogeneous products. The combination of this controlled salting process, by using smoke-flavoured salt, and vacuum packaging has also been studied with a view to obtaining smoked salmon with similar characteristics to currently marketed products (Rizo et al., 2013). This methodology was able to accelerate NaCl absorption and dehydration, and can therefore cut the total processing time without affecting physico-chemical parameters and sensory traits as compared with traditional smoked salmon. Other studies have been focused on the use of smoke condensates and liquid smoke as an alternative to the traditional smoking process (Muratore and Licciardello, 2005; Muratore et al., 2007; Sullen et al., 2003). The use of smoke flavourings apart from providing the typical smoke flavour to this type of products, can also avoid the occurrence of harmful components for human health and the environment generated by traditional smoking techniques (Martínez et al., 2007).

Recently, materials with high water vapour transmission rates have been investigated. Currently there are very few applications for these new materials in food technology, being these focused mainly on dry ageing of beef (Ahnström et al., 2006; DeGeer et al., 2009; Dikeman et al., 2013; Li et al., 2013). The use of highly water vapour-permeable bags (WP) facilitates the control of product dehydration by managing the temperature and humidity conditions, as with the traditional methods (unpacked). Yet at the same time, it minimises the risk of microbial contamination.
DeGeer et al. (2009) stated that this type of bags helps obtain higher meat yields and lower microbial counts as compared with the traditional dry ageing processes, and does not affect the sensory traits of the meat product. For this reason, we considered that a combination of a one-step smoking–salting process with WP bags would help obtain smoke-flavoured fish with similar sensory traits to smoke products obtained by traditional methods and would optimise yields, reduce waste, speed up processes, maintain the hygienic quality during processes, and facilitate transportation and distribution at the same time. This could improve the methodology previously described, in which a controlled salting process was combined with vacuum packaging.

The aim of this study was to establish the optimal processing conditions (salt dose, type of packaging and RH of drying) to develop a new smoking–salting procedure using water vapour permeable bags in order to obtain smoke-flavoured salmon.

2. Material and methods

2.1. Materials

Aquacultured salmon (Salmo salar) fillets (n = 9) from a land-based farm in Norway (Marine Harvest, Bergen, Norway), of the commercial size 1.4–1.8 kg were purchased from a local market in the city of Valencia (Spain) and were transported to the laboratory under refrigeration. Upon arrival at the laboratory, the fillets were trimmed to remove bones, fins and any visible adipose tissue. Then salmon fillets were cut into 4 cm portions to obtain six portions per fillet (54 samples in all were obtained). Average weight of fish portions was 151 ± 35 g and thickness between 2 and 3 cm.

The sodium chloride used for the smoking–salting process was supplied by Panrec Quimica, S.A. (Barcelona, Spain), and the natural liquid smoke HARDWOOD AFS 10 was provided by Amcan ingredient Ltd. (Le Chesnay, France). Two types of plastic bags packaging were used for this study: water vapour permeable bags (WP) were supplied by TUB-EX ApS (Taars, Denmark) (size: 200 × 300 × 0.04 mm; water vapour transmission rate: 5000 g/50 μl/m²/24 h (38 °C/50% RH); high barrier bags (HB) (size 200 × 300 × 0.12 mm, water vapour transmission rate 1.8 g/120 μl/m²/24 h (23 °C)/85% RH), supplied by Productos Pilarica, S.A. (Valencia, Spain). Two batches of smoked salmon from two different brands were used to determine the target physico-chemical parameters for the new product. Raw material of these products was Norwegian aquacultured salmon and they were processed using traditional cold-smoking techniques (dry salting, followed by smoking in a smoking chamber).

2.2. Experimental design

In order to establish the optimal salting conditions of the new method, the effect of the amount of salt dosed, RH in the drying chamber, and packaging permeability on the physico-chemical properties of the final product were all studied. These conditions were set in order to obtain smoke-flavoured salmon with similar characteristics to currently marketed products. Values considered as reference were obtained from the commercial products analysed (moisture, salt content and a_w).

Salmon portions were submitted to a simultaneous smoking–salting process (Fig. 1). The smoking conditions and salting parameters to be tested were selected based on previous studies with minor modifications (Fuentes et al., 2008). Fish samples were smoked by spraying the fillet surface with liquid smoke that was diluted with distilled water (60 ml/100 ml solution) for 30 s, followed by a salting procedure based on thermodynamic control. Salting was carried out by dosing a previously established amount of NaCl over the fillet surface. The amount of salt added to each sample was calculated from the initial weight of the fish portion and the initial water weight fraction (aw), according to procedure established by Fuentes et al. (2008). In this study, three salt dose concentrations were considered: 4, 6, and 8 g salt/100 g fresh salmon. Then the salmon portions were randomly divided into two groups, one group was packed into WP bags and the other group was packed into HB bags. All the samples were vacuum-packaged with a vacuum packaging machine (Tecnorip EV-25-CD, Barcelona, Spain). It should be noted that the vacuum conditions for the WP samples were not maintained throughout the process, vacuum packaging was used to ensure the initial contact between fish and the packaging material since air can pass through the bag.

Samples from the two groups were randomly divided into three new batches (6 batches in all; one batch per group of samples (WP and HB) was introduced into a drying chamber at 5 °C for 24 h (Binder mod. KBF Tuttlingen, Germany) with an established RH (50%, 60% or 70%). Afterwards, the salmon portions were removed from the bags and the exudate formed during the process was weighed. Fish samples were introduced into saturated brine under constant stirring for 30 s to remove any traces of salt attached to the surface. Finally, they were dried with absorbent paper, weighed and left at 4 °C for 24 h to ensure a homogeneous salt distribution onto the pieces.

Analyses of moisture, lipid content, NaCl content, pH and a_w were carried out on the fresh salmon and the smoked samples. Three samples were used for each condition (n = 3), and the analyses were done on each sample in triplicate, except for pH, which was measured in quintuplicate.
2.3. Analytical determinations

Moisture content was determined according to the AOAC method 950.46 (1997). The lipid content of the samples was determined by Soxhlet extraction using petroleum ether according to the AOAC method 991.36 (AOAC, 1997). Sodium chloride content was determined following the procedure described by Fuentes et al. (2010b) with an automatic Sherwood Chloride Analyzer Model 926 (Sherwood Scientific Ltd., Cambridge, UK). pH measurements were taken using a digital pH-meter micropH 2001 (Crismon Instruments, S.A., Barcelona, Spain) with a puncture electrode (Crismon 5231) in five different sample locations. Water activity (aw) was measured in minced samples with a fast water activity-meter (GBX scientific FA-st/1, Cédex, France).

Changes in the total mass of the salmon portions (∆M) throughout the salting process were estimated from the weight (M) of the samples (at sampling time t and 0), respectively by Eq. (1). Likewise, the total sodium chloride concentration in the liquid phase (xNaCl) was estimated from the weight fractions of water (xw) and sodium chloride (xNaCl), in accordance with Eq. (2)

\[
\Delta M_t = \left( M_t - M_0 \right) / M_0
\]

\[
x_{NaCl} = \frac{x_{NaCl}}{x_w + x_{NaCl}}
\]

2.4. Sensory analysis

After having established the appropriate smoking–salting conditions for the new process, a sensory assessment was made in order to evaluate the sensory acceptance of the obtained products. The sensory analysis was conducted with the smoke-flavoured salmon developed by the new process. In this case the smoking process was carried out by using the selected conditions (WP-50, WP-60, and WP-70 with a salt dose of 8 g NaCl/100 g fish) and commercial smoked salmon. The smoking process was similar to that previously described, but in this case, only the selected salt dose level was employed. Then the smoked salmon samples were filleted, vacuum-packed and kept at 4 °C until the sensory evaluation was made (24 h approximately after finishing the whole process).

The sensory analysis of the smoke-flavoured salmon samples was undertaken by 32 non-expert and untrained assessors who are regular consumers of smoked products. Tests were done with the semi-structured scales (AENOR, 2006) by which attributes such as appearance, colour, odour, intensity of smoke odour, taste, intensity of saltiness and global acceptance were evaluated. These attributes were selected as being the most important and representative for both industry and consumers (Rodrigues et al., 2005 cited by Fuentes et al., 2010b). Each assessor answered a questionnaire with 8 cm lines and three anchor points (0 = unpleasant, 4 = acceptable, and 8 = pleasant) for all the attributes, except for smoke odour and saltiness intensity, where the anchors corresponded to insufficient, optimum, and excessive (0, 4, and 8, respectively). Each assessor evaluated four samples served at room temperature and coded with a 3-digit random number.

2.5. Statistical analysis

A multifactor ANOVA was conducted in the first part of the study for each physico-chemical parameter to evaluate the effect of salt dose, packaging conditions, RH during salting–smoking, and their interactions. For the sensory analysis, a one-way ANOVA was performed for each sensory attribute evaluated in order to test if there were significant differences between the smoke-flavoured samples. The least significance procedure (LSD) was used to test for the differences between averages at the 5% level of significance. The data were statistically processed using Statgraphics Centurion XVI (Manugistics Inc., Rockville, MD, USA).

3. Results and discussion

3.1. Characterisation of raw material and commercial product

Moisture, lipid content, sodium chloride, pH and aw values of the raw material and the commercial smoked salmon samples are shown in Table 1.

The results obtained in the physico-chemical characterisation of the fresh salmon used as raw material were similar to those reported in other studies (Duun and Rustad, 2008; Fernández-Segovia et al., 2012; Rørå et al., 2004). In general, the uptake and distribution of salt into the fillets in the salting processes depends on several factors, such as the salting method, salt dose, muscle thickness and other intrinsic fish factors like composition and post-mortem state (Rørå et al., 1998; Mørkøre and Rørvik, 2001). Accordingly, the correct characterisation of the raw material is especially important for selecting the most appropriate processing conditions. Some physico-chemical parameters, such as the moisture and lipid content of the raw material, strongly influence muscle behaviour during processing because these parameters modify salt uptake and moisture loss, and can therefore determine the final product characteristics. For this reason, it is important to adjust the smoking–salting conditions depending on the moisture and lipid content of the raw material in order to ensure typical product characteristics (Barat et al., 2006).

For the commercial smoked salmon, the observed values agree with those for cold smoked salmon of diverse origins reported by other authors (Cardinal et al., 2004; Fuentes et al., 2010a). Smoked salmon showed lower values of moisture, but higher salt values, which implied a lower aw value compared to fresh fish. The analysed smoked product fulfilled the French standard for smoked salmon NF V45-065 (1997) cited by Rørå et al. (2004), which establishes a maximum lipid content of 18% and 74% water content in the fat-free product. No significant differences were found among batches in any of the analysed parameters. However, some studies have found high variability for such products for their moisture content, salt, aw and their sensory attributes (Truelstrup Hansen et al., 1998; Cardinal et al., 2004). The selection of homogeneous raw material would reduce this variability which is, in most cases, due to differences in fish muscle composition (Espe et al., 2002; Mørkøre and Rørvik, 2001); however, this variability cannot be completely eliminated since the process highly affects the final product characteristics.

As Table 1 shows, the pH values were higher for the commercial smoked salmon if compared with fresh salmon. However, salting processes are associated with lower pH values of fish muscles in relation to the greater ionic strength of the internal solution in cells due to the effect of salt (Leroi and Joffraud, 2004).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Physico-chemical parameters of raw material and commercial smoked salmon. Mean values ± SD (n = 3).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raw material</strong></td>
<td><strong>Commercial smoked salmon</strong></td>
</tr>
<tr>
<td><strong>Brand 1</strong></td>
<td><strong>Brand 2</strong></td>
</tr>
<tr>
<td>Moisture (g/100 g)</td>
<td>65.39 ± 1.93</td>
</tr>
<tr>
<td>Lipid (g/100 g)</td>
<td>12.48 ± 3.47</td>
</tr>
<tr>
<td>NaCl (g/100 g)</td>
<td>0.20 ± 0.01</td>
</tr>
<tr>
<td>pH</td>
<td>6.19 ± 0.08</td>
</tr>
<tr>
<td>aw</td>
<td>0.993 ± 0.003</td>
</tr>
</tbody>
</table>
A higher pH value might be explained by the production of basic compounds such as ammonia, trimethylamine and other biogenic amines during storage which cause a progressive increase in pH (Goulas and Kontominas, 2007). According to the characteristics of our raw material and the values of the physico-chemical parameters of the reference product, the processing conditions of the new method should be selected to allow moisture reduction over 5% and the salt dose should be established to achieve a final salt content close to 4% by considering salt loss with exudates.

3.2. Study of the smoking–salting process

The smoking–salting process, regardless of the employed conditions, significantly lowered the water content and \(a_w\) values, and also increased the NaCl concentration, if compared with fresh salmon (Fig. 2). Dehydration and NaCl absorption into fish flesh lead to lower \(a_w\) values. As expected, the salt concentration increased with higher salt doses regardless of type of packaging and RH employed, and the \(a_w\) values consequently lowered. For the same salt dose level, the salting procedure combined with HB led to a higher salt content in the final product as compared with WP. The effect of vacuum packaging on salt absorption has been observed in other studies. Rizo et al. (2013) established that vacuum packaging speeds up NaCl absorption and could, therefore, accelerate the whole process, reducing the total processing time.

The moisture and \(a_w\) values of the WP samples were affected by RH since the samples processed at the lowest RH (WP-50) exhibited the lowest moisture and \(a_w\) values. It is interesting to note that the salt content of the WP samples did not differ among samples, which indicates that salt absorption is not affected by RH at the levels studied. The WP-70 samples showed the highest \(a_w\) value and moisture content irrespectively of salt dose, and the established reference value was not reached in any case.

The WP-60 salmon samples with an 8% salt dose gave the closest moisture and salt content and \(a_w\) values to the reference value. Water activity (\(a_w\)) is directly related with the microbiological load of salted and smoked products. Therefore, it can be considered a decisive parameter to ensure smoked fish safety. In this sense, although the use of 50% RH implied a lower moisture and \(a_w\) in the fish samples, a higher risk of hardening and crust formation in the surface could appear. Crust formation leads to heterogeneous dried product with a highly dried surface and a poorly dried core (Andrés et al., 2007). These conditions should be corroborated with the sensory analysis.

The physico-chemical parameters of the smoke-flavoured salmon obtained by the new smoking–salting process using the different conditions are provided in Table 2. Weight loss increased in samples when the salt dose increased, and these data were higher as RH lowered. Regardless of the salt dose, weight loss was found to be lower in the HB samples as compared with the WP ones; this fact can be attributed to the higher dehydration observed in the WP samples, which led the water from fish muscle to flow out. Regarding lipid content, differences between samples were observed, and are possibly due to the existence of the initial variability among the fresh fish portions employed since lipid content is typically heterogeneously distributed in fish fillets, just as other studies have described (Katicou et al., 2001). The smoking–salting process led to lower pH values in the smoked salmon samples, except for the WP-70 samples (Table 2) given the effect of salt, which increases the ionic strength of the intracellular solution, as earlier mentioned.

According to Codex standard for smoked fish, smoke-flavoured fish and smoked dried fish (Codex, 2013), the variability in amount of salt in the aqueous phase could have important implications on the likelihood of Clostridium botulinum toxin formation. In particular, smoked fish and smoke-flavoured fish where the smoke flavour is provided by artificial flavour blends, 5% aqueous phase salt (\(z_{NaCl} = 0.05\)) would be required in order to provide complete protection at temperatures between 3 °C and 10 °C. Based on this standard, the products obtained by any of the treatments tested fulfil this requirement.
The results obtained in the multifactor ANOVA for each physico-chemical parameter are shown in Table 3. In general, the statistical analysis revealed that the amount of salt dosed and the packaging conditions strongly influence all the parameters evaluated, where the effect of packaging was greater as compared to the salt employed for all the variables considered. The interactions between salt and packaging did not affect the variables studied. The interactions of residual brine using WP bags, and reducing the amount of salt employed with controlled salting, can help diminish the final volume of brine waste generated by the process. By using WP bags, RH conditions can be adjusted according to the specific raw material characteristics of each batch, which helps achieve a product with optimal physico-chemical characteristics. By using this methodology, modifications in other process parameters can be studied, such as temperature, air renewal and drying cycles, as these parameters correlate directly with water flow. Furthermore, the smoking–salting process inside a bag can offer other advantages over traditional methods (unpacked), such as protecting the product against possible contaminations and maximising yields (DeGeer et al., 2009).

Among all the process conditions tested, the use of WP bags with 60% RH (WP-60), and an 8% salt dose was considered the most appropriate because it enables the achievement of smoke-flavoured fish with similar $d_{w}$, moisture and salt contents to the reference product.

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>$S$ (g salt/100 g)</th>
<th>$\Delta M_t$</th>
<th>% Lipid</th>
<th>$\phi H$</th>
<th>$z_{NaCl}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HB</td>
<td>4</td>
<td>-0.03 ± 0.003$^{aB}$</td>
<td>10.84 ± 0.56$^{aB}$</td>
<td>6.09 ± 0.09$^{aB}$</td>
<td>0.058 ± 0.003$^{c}$</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>-0.04 ± 0.010$^{aB}$</td>
<td>10.68 ± 0.81$^{aB}$</td>
<td>6.11 ± 0.14$^{aB}$</td>
<td>0.070 ± 0.005$^{c}$</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>-0.05 ± 0.006$^{aB}$</td>
<td>12.92 ± 1.22$^{aB}$</td>
<td>6.13 ± 0.09$^{aB}$</td>
<td>0.078 ± 0.007$^{c}$</td>
</tr>
<tr>
<td>WP-50</td>
<td>4</td>
<td>-0.09 ± 0.003$^{aB}$</td>
<td>12.73 ± 0.43$^{aB}$</td>
<td>6.17 ± 0.03$^{aB}$</td>
<td>0.053 ± 0.006$^{aB}$</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>-0.09 ± 0.004$^{aB}$</td>
<td>12.22 ± 0.05$^{aB}$</td>
<td>6.17 ± 0.04$^{aB}$</td>
<td>0.064 ± 0.005$^{c}$</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>-0.10 ± 0.006$^{aB}$</td>
<td>16.56 ± 1.59$^{aB}$</td>
<td>6.17 ± 0.04$^{aB}$</td>
<td>0.070 ± 0.002$^{aB}$</td>
</tr>
<tr>
<td>WP-60</td>
<td>4</td>
<td>-0.06 ± 0.013$^{c}$</td>
<td>8.96 ± 3.68$^{aB}$</td>
<td>6.09 ± 0.00$^{c}$</td>
<td>0.055 ± 0.006$^{aB}$</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>-0.08 ± 0.008$^{c}$</td>
<td>10.41 ± 0.50$^{aB}$</td>
<td>6.04 ± 0.04$^{c}$</td>
<td>0.054 ± 0.008$^{aB}$</td>
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<td></td>
<td>8</td>
<td>-0.08 ± 0.012$^{c}$</td>
<td>9.39 ± 1.88$^{aB}$</td>
<td>6.08 ± 0.03$^{c}$</td>
<td>0.062 ± 0.007$^{aB}$</td>
</tr>
<tr>
<td>WP-70</td>
<td>4</td>
<td>-0.05 ± 0.011$^{CD}$</td>
<td>12.20 ± 1.90$^{aB}$</td>
<td>6.26 ± 0.01$^{c}$</td>
<td>0.049 ± 0.005$^{aB}$</td>
</tr>
<tr>
<td></td>
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<td>-0.06 ± 0.012$^{CD}$</td>
<td>10.75 ± 1.90$^{aB}$</td>
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<td>0.058 ± 0.008$^{aB}$</td>
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<tr>
<td></td>
<td>8</td>
<td>-0.06 ± 0.004$^{CD}$</td>
<td>12.80 ± 0.56$^{aB}$</td>
<td>6.26 ± 0.04$^{c}$</td>
<td>0.056 ± 0.008$^{aB}$</td>
</tr>
</tbody>
</table>

Different lower-case letters indicate significant differences for salt dose factor ($S$). Different capital letters indicate significant differences for packaging conditions factor ($P$). ($p < 0.05$).

$\Delta M_t$: weight loss; % Lipid: g lipid/100 g fish; $z_{NaCl}$: g salt/g liquid phase.

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>$S$</th>
<th>$P$</th>
<th>$S \times P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>12.44$^{**}$</td>
<td>13.62$^{**}$</td>
<td>1.59$^{**}$</td>
</tr>
<tr>
<td>Lipid content</td>
<td>3.23$^{**}$</td>
<td>11.78$^{**}$</td>
<td>1.93$^{**}$</td>
</tr>
<tr>
<td>NaCl content</td>
<td>8.83$^{**}$</td>
<td>9.81$^{**}$</td>
<td>1.33$^{**}$</td>
</tr>
<tr>
<td>$\phi H$</td>
<td>0.14$^{**}$</td>
<td>12.71$^{**}$</td>
<td>0.33$^{**}$</td>
</tr>
<tr>
<td>$d_{w}$</td>
<td>10.72$^{**}$</td>
<td>10.84$^{**}$</td>
<td>0.67$^{**}$</td>
</tr>
<tr>
<td>$\Delta M_t$</td>
<td>13.71$^{**}$</td>
<td>125.83$^{**}$</td>
<td>0.77$^{**}$</td>
</tr>
<tr>
<td>$z_{NaCl}$</td>
<td>2.69$^{**}$</td>
<td>7.68$^{**}$</td>
<td>1.32$^{**}$</td>
</tr>
<tr>
<td>Exudate</td>
<td>15.68$^{**}$</td>
<td>11.77$^{**}$</td>
<td>1.39$^{**}$</td>
</tr>
<tr>
<td>Moisture</td>
<td>8.61$^{**}$</td>
<td>135.43$^{**}$</td>
<td>3.51$^{**}$</td>
</tr>
</tbody>
</table>

ns: No significant.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$. 

### Fig. 3

Percentage of exudate generated during smoking–salting process. Mean values ± SD ($n = 3$). Bars indicate the standard deviation. Different lower-case and capital letters indicate significant differences for salt dose ($S$) and packaging conditions ($P$) factors, respectively ($p < 0.05$).
the 8% sale dose. After processing, the moisture, lipid content, sodium chloride, pH, and $a_w$ of smoke-flavoured product were determined. These analyses were also performed with the commercial product. The characterisation of the salmon products (those obtained by the new technology and the commercial ones) did not show significant differences in any of the parameters analysed (ANOVA data not shown). These values fell within the range of values for this type of products (Fuentes et al., 2010a). The overall scores marked by the assessors for the sensory attributes of the different evaluated samples are depicted in Fig. 4. No significant differences were recorded between samples for any evaluated attribute ($p > 0.05$; ns), although the scores for taste, odour and global acceptance were slightly higher for the commercial smoked salmon. Nevertheless, the commercial samples obtained lower scores for the colour attribute than those samples processed by the new smoking–salting process.

The mean values scored by the assessors for smoke odour intensity and saltiness are shown in Fig. 5.

For smoke odour intensity, all the samples obtained scores that came very close to the optimal value. No significant differences ($p > 0.05$) were observed among samples. The WP-60 samples came closer to the score considered optimum, while the commercial smoked salmon and the samples WP-70 scores were the further away from the optimum value. In this case, the smoke odour intensity of commercial samples was considered by the panelists as excessive. Likewise, no differences were found among samples for saltiness, and the scores for this attribute of the WP-70 and commercial smoked salmon were further from the “optimum” score. According to the sensory evaluation results, it may be stated that the sensory attributes of the smoked salmon obtained by the new methodology are perceived with the same degree of acceptance as the commercial smoked salmon.

This work provides a new alternative to the traditional salting and smoking processes. Further studies on the shelf-life of the product obtained will be necessary to establish if this product could be commercialized.

4. Conclusions

The salting procedure using HB led to a higher salt concentration in the final product as compared with the WP bags. In the WP samples, the decrease in RH in the drying chamber brought about a more marked reduction in the moisture and $a_w$ values. However, salt uptake was not affected by the RH set. Among the salt levels employed, the WP-60 samples with an 8% salt dose exhibited the closest levels of $a_w$, salt content and moisture to the reference values. Use of 50% and 60% of RH led to the evaporation of the water released by the muscle. The sensory attributes of the smoke-flavoured salmon obtained similar scores to the commercial product. These results indicate that this new methodology is suitable to obtain smoke-flavoured salmon with similar physico-chemical characteristics and consumer acceptance to a commercial smoked salmon.

The new smoking–salting process minimises brine waste, reduces processing steps and facilitates fish handling during chain production, which could prove to be a major advantage as regards maintaining hygienic quality.

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