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Hot smoked Atlantic mackerel (*Scomber scombrus*)

Effects of catch season, frozen storage time of raw material (fillets) and chilled storage time of finished product, on colour and sensory characteristics

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Report

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Tittel: Varmrøykt makrell Effekt av fangstsesong, fryselagringstid av råstoff (filet) og kjølelagringstid av ferdig produkt, på farge og sensoriske egenskaper.	*Accessibility:* **Open**
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Summary/recommendation:

Two trials have been carried out with hot-smoking of Atlantic mackerel in order to investigate the effect of different raw material (fillets), on product quality and shelf-life. Fillets produced from trawled, Icelandic mackerel, caught in September, from Norwegian purse-seine caught fish from November, and from trawled mackerel caught in January, were hot smoked, vacuum packaged and stored at 4 °C. After one and seven weeks, the colour was measured instrumentally, and the samples were evaluated by a sensory panel.

The results indicate that neither catch season, nor frozen storage time significantly affected the processing yield. The colour of the smoked fillets changed during storage; both the redness and the yellowness decreased over the 6 week storage period, as did the lightness. In the trial, frozen fillets stored for more than eight months were used. None of the smoked samples, however, were characterised as rancid or oxidized. The products from the three different catch-months were, in fact, only significantly different with respect to salty and acid taste. The results show that the smoking process to some degree evens out the differences in raw material freshness and composition.

Summary/recommendation in Norwegian:

Det er gjennomført to forsøk med varmrøyking av makrell, for å undersøke effekten av ulike råstoff (filet) på produktkvalitet og lagringsegenskaper. Filet produsert av islandsk trålfanget makrell i September, av norsk notfanget fisk fra November og av norskprodusert notfanget fisk fra Januar, ble varmrøykt, vakumpakket og lagret ved 4 °C. Etter en og sju uker ble fargen målt instrumentelt og prøvene ble bedømt av et sensorisk panel.

Resultatene viser at hverken fangstsesong eller fryselagringstid ga noen signifikant effekt på prosessutbyttet. Fargen på det røykte produktet endret seg under lagring; verdiene for lyshet, rødhet og gulhet avtok under lagringen.

I forsøket ble det brukt fileter som var fryselagret, noen i mer enn 8 måneder. Ingen av prøvene ble imidlertid karakterisert som harske/oksiderte. Produktene fra de tre fangst-månedene var signifikant forskjellige kun når det gjaldt syrlighet og salt smak. Resultatene indikerer at røykeprosessen i noen grad jevner ut ulikheter i råstoffets sammensetning og ferskhet.

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1 Introduction

The degree of processing of Nordic mackerel is low. The fish is exported mainly as block-frozen, either whole or as headless and gutted fish. Further processing of fresh mackerel into fillets may well be economically viable, but the industry has limited knowledge and information on which raw material is best suited for filleting, with respect to season, catching method and handling. This lack of information hinders the Nordic industry in developing the sector further and in attaining a competitive advantage globally in further processed goods.

Atlantic mackerel is one of the most important of the small Nordic pelagic fish species. Although filleting of mackerel can be economically feasible, the variation in the composition of the fish may limit the processing options.

One of the project aims was to investigate the variation of the caught fish from the Icelandic jurisdiction (June-September) and fish caught within Norwegian and EU waters (September until spring time). Additionally, to focus on the whole value chain of the fish from catch to customer; not only by looking at the effects of seasonality on the frozen commodity to be sold to customers but also on the final food products and how the seasonality may affect the quality of the products. For mackerel, a major final product is smoked mackerel, and it was decided to investigate the effects of some main quality criteria related to season, catch method and storage on the product quality characteristics of hot smoked products.

A number of studies have been carried out on smoked mackerel, but few studies are available that investigate these parameters. Kolodziejska *et al.* (2002) studied the microbial and sensory quality of hot smoked mackerel during storage for 3 weeks at refrigerated temperatures. They found that the higher microbial growth at 8 °C, as compared to 4 °C, was correlated also to salt-content. The difference in microbial growth, however, was not related to sensory attributes during the first two weeks of storage. The effect of frozen storage of raw material (whole), was studied by Zotos *et al.* (1995). These authors found no statistically significant difference in sensory scored, caused by frozen storage (-20 °C) of the raw material for up to 33 weeks.

2 Materials and Methods

The stated goal to study both seasonal variation and the potential effect of the raw material storage time on the final products, was challenging for several reasons:

The raw material sources to be included in the trial were caught at different times (from September to January). Due to challenges with sample transport etc. the September raw material did not become available for the trial until in February the year after. This gave rise to limitations with respect to varying the frozen storage time, independently of the catch season. Furthermore it would also have been very resource demanding to conduct trials in which the fillet storage time was kept constant. Such a setup would require numerous trials, both for production of smoked fish, and also sensory analysis sessions. In addition, one would lose the possibility for inter sample comparison.

Hence is was decided to include fillets from three different seasons in two trials. In this way both fillet storage time and catch month would be varied at the same time. But, on the other hand, with two trials, fillet storage time would vary, and since the same three raw materials were included in both trials, comparison between groups was achieved within each trial.

2.1 Raw material

The raw material for these trials were glazed fillets produced by Sildarvinnslan [IS] in week 35, 2016 (September), and glazed fillets from Pelagia [NO], produced in week 45, 2016 (November) and in week 4, 2017 (January).

The samples were relatively similar with respect to composition, as shown in Figure 1:

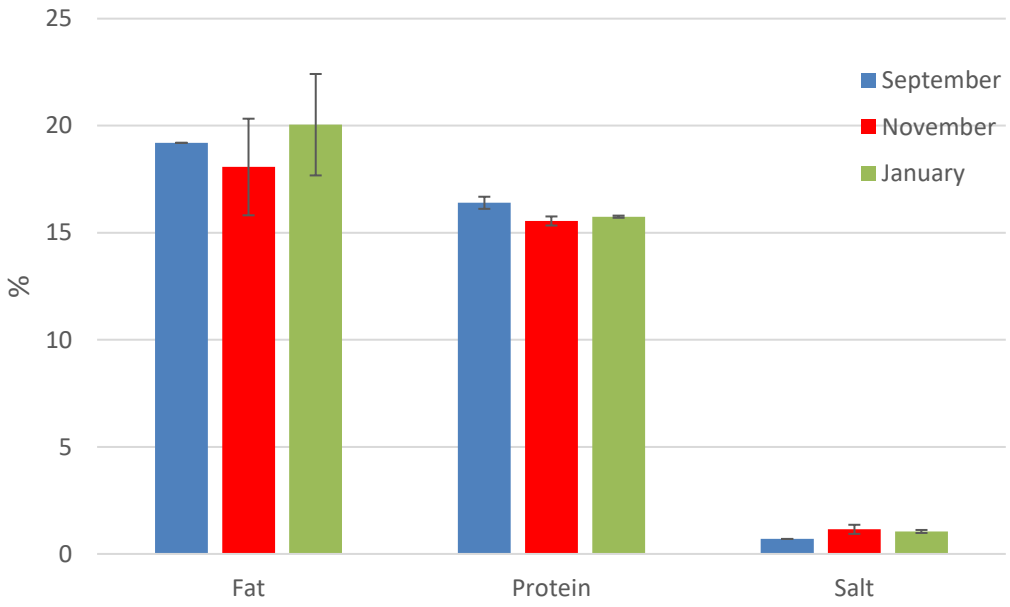

Figure 1 Content of fat, protein and salt (average ± SD, n=2) in the raw material used for both trials.

The largest variation was seen in the most important parameter, the fat content, which ranged from 18.1% to 20.0%. The protein content was around 16%. Interestingly the salt content was higher (> 1%) in the November and January fillets.

In addition to seasonal effects like composition, the effect of storage time was also investigated. An overview of the storage time as frozen fillets is shown in Table 1.

Table 1 Overview of samples; catch month and frozen storage time for fillets.

Month	Days stored as frozen fillet					
September (2016)					193	242
November (2016)			124	173		
January (2017)	49	98				

The fillets were stored loosely wrapped in PE-film inside carboard boxes, at -20 °C, prior to processing. The trials were carried out in March and in May,2017. Fillets from each production, were processed for subsequent sampling and analysis. 15 fillets were used per sampling; 10 fillets for sensory and 5 fillets for chemical/physical analyses.

2.2 Processing

The smoking process consists of a number of processing steps that can be conducted in several ways. In this trial it was decided to aim for a salt content of 3%, and to use a standard hot-smoking procedure.

2.2.1 Salting

Salting was carried out in 80 °Be brine at 10 °C for 4 minutes. This procedure was determined after pre-trials, aiming for a salt-content of 3%.

2.2.2 Smoking

The fillets were dried and hot-smoked under controlled conditions at Nofima AS simulating a commercial processing protocol. Processing was performed in a Bastramat C1500 smoking cabinet equipped with a BASTRA Profi1000 microprocessor (Bayha & Strackbein GmbH, Arnsberg, Germany). A Bastra FR 100 smoke generator (Bayha & Strackbein GmbH, Arnsberg, Germany) supplied with Reho Räucher Gold HBK 750/2000 wood chips (J. Rettenmaier & Söhne GmbH, Rosenberg, Germany) was used for smoke generation. The fillets were randomized on the grids in the smoking chamber. The processing protocol was the deefualt setting for hot smoking of the smoking cabinet. The process details are shown in Table 2. Before vacuum packaging and storage, the fillets were rested in room temperature for approximately 30 minutes. The chamber air velocity during processing was in the range 0.5 to 0.8 m/s.

Table 2 The programmed processing protocol for hot smoking of mackerel.

Step #	1	2	3	4	5	6	7	8	9	10
Process	Dry	Smoke	Red	Dry	Smoke	Red	Dry	Smoke	Red	Dry
T [°C]	50	55	55	55	55	55	55	55	55	55
Humidity	40	50	50		50	50		50	50	
t (min)	40	15	10	10	15	10	5	10	10	5

2.2.3 Vacuum packaging and storage

After smoking, the fillets were left for an hour in room temperature and weighed prior to being vacuum packaged (99.9%) on a Webomatic C60 D/W/U (Webomatic Maschinenfabrik GmbH, Bochum, Germany) in PA/PE bags (Polyamide/Polyethylene, 90 µ). The samples were stored (4 °C) and sampling/analysis was carried out after 1 and 7 weeks.

2.3 Analyses

Three samplings were conducted during the two trials. This was arranged intentionally, in order to strengthen the intercomparison between batches, specifically for the sensory analyses.

2.3.1 Dry matter

The dry matter content of the samples (5 g) was determined gravimetrically (n = 4) after drying at 105 °C for 16 to 18 h to constant weight (NMKL, 1991).

2.3.2 Salt

The salt content in smoked fillets was determined by the use of a modified potentiometric titration method (ISO, 2006). Homogenized samples (1 g, n = 3) were diluted with de ionized water (50 ml, heated to 55 °C), left for 1 h and titrated in an automated titration unit consisting of a T70 Titrator with one burette for nitric acid and one for silver nitrate, an “In Motion” Sample Changer, a DM141-SC Combined silver ring electrode and a DGi115-SC pH electrode (all components by Mettler Toledo, USA). The NaCl content was determined from the analyzed Cl-content.

2.3.3 Colour

Hunter parameters of L*, a^* and b^* were measured on the surface of the smoked mackerel samples (n = 5), by the use of a digital photo imaging color-measuring system (DigiEye full system, VeriVide Ltd., Leicester, UK). The samples were placed in a standardized light-box with daylight (6500 K) and photographed with a calibrated digital camera (Nikon D80, 35mm lens, Nikon Corp., Japan). The pictures were analyzed with DigiPix software (VeriVide Ltd., Leicester, UK) and the color was quantified. L* describes the products lightness (L* = 100 = white, and L* = 0 = black), a* describes the intensity of color on the red–green axis (a* > 0 = red, and a* < 0 = green) and b* the intensity of color on the yellow–blue axis (b* > 0 = yellow, and b* < 0 = blue).

2.3.4 Process yield and exudates

The individual weight of 5 labelled fillets from each group (month), was recorded throughout the process; as thawed raw material, and after the salting, smoking and packaging/storage. These weights were used to calculate the process yield in both trials.

The amount of exudates in the packages following storage were calculated according to the formulae (x):

$EX = [(W_{smoke} - W_{store})/W_{smoke}]*100\%$ (x)

where W_{smoke} = weight of smoked fillet (g) and W_{store} = weight of smoked and stored fillet (g).

2.3.5 Sensory analysis

The smoked mackerel samples were subjected to sensory analysis after heat processing using Quantitative Descriptive Analysis (QDA®) (Stone & Sidel, 2004). Eight attributes were defined and described for smoked mackerel fillets within odor (rancid), taste (smoke, rancid, salty, acid) and texture (firmness, juiciness and fattiness (mouthfeel)). The attributes were modified from Kolodziejska *et al.* (2002) using a structured 9-point scale from 1 (low intensity) to 9 (high intensity). The smoked mackerel were prepared for the taste sessions, by cutting the fillets in 1 cm slices, of which each was placed in a plastic cup, which was labeled with a three-digit code and subsequently covered with aluminum foil. The QDA was carried out by five panelists; trained according to ISO 8586 (ISO, 2012) and familiar with the QDA method and sensory analysis of smoked mackerel. A computerized system, EyeQuestion Software version 3.5 (Logic8 BV, Wageningen, the Netherlands), was used by the panelists' for collecting data.

2.3.6 Statistics

Average score and standard deviation of attributes were calculated. The data was further analyzed using analysis of variance (ANOVA, General Linear model) in MINITAB® Version 18 (Minitab Inc., State College, Pennsylvania, USA). Significant differences ($p < 0.05$) were determined using Tukey's pairwise comparison test. Month and Product Storage (Short, Long) were considered as factors, and Fillet storage (Days) as covariate.

3 Results and discussion

3.1 Raw material, Dry matter and salt content

Mackerel is characterized by substantial variation. In size and in fat content. The average weight of the fillets used in Trial 1, is shown in Table 3. As can be seen from the table, the January raw material was significantly ($p < 0.05$) lighter than the September and November fillets. And the variation in weight, was much smaller in the January fillets.

Table 3 Raw material and product characteristics. Different superscripts, denote statistically significant ($p < 0.05$) differences.

Sample	Raw material (n=5)		Packaged, smoked sample (n=8)			
Month\Type	Fillet weight (g)		Dry matter [%]		Salt [%]	
September	96.3	± 23.2[a]	47.4	± 1.76	2.8	± 0.3[a]
November	95.9	± 17.8[a]	46.6	± 0.97	3.3	± 0.4[b]
January	90.5	± 10.0[b]	43.4	± 2.01	3.3	± 0.4[b]

The dry matter content reflects the content of mainly fat and protein and salt/minerals. The results from the dry matter analyses of packaged products are presented in table 2. In Atlantic mackerel, the fat content is very variable, and the highest fat content can be observed during the autumn months. The products made from raw material from September and November has the highest dry matter content, significantly higher than the January samples. This could be because these contain the most fat, although the proximate composition of the raw material (Figure 1) indicates otherwise. Further, the results show that the dry matter content is quite similar after processing, not necessarily reflecting the initial differences.

The salt content is a very important parameter for smoked mackerel. It affects the taste profile, but it can also be expected to affect the yield and the texture properties. The salt content of the samples is shown in Table 2. The results indicate that the September samples are less salty that the others. This may be attributed to the lower initial salt content (Figure 1).

3.2 Process yield and exudates

An estimation of process yield was based on the recorded weight of individually marked fillets (raw material) and after the salting, smoking and packaging/storage. The results are shown in Figure 2.

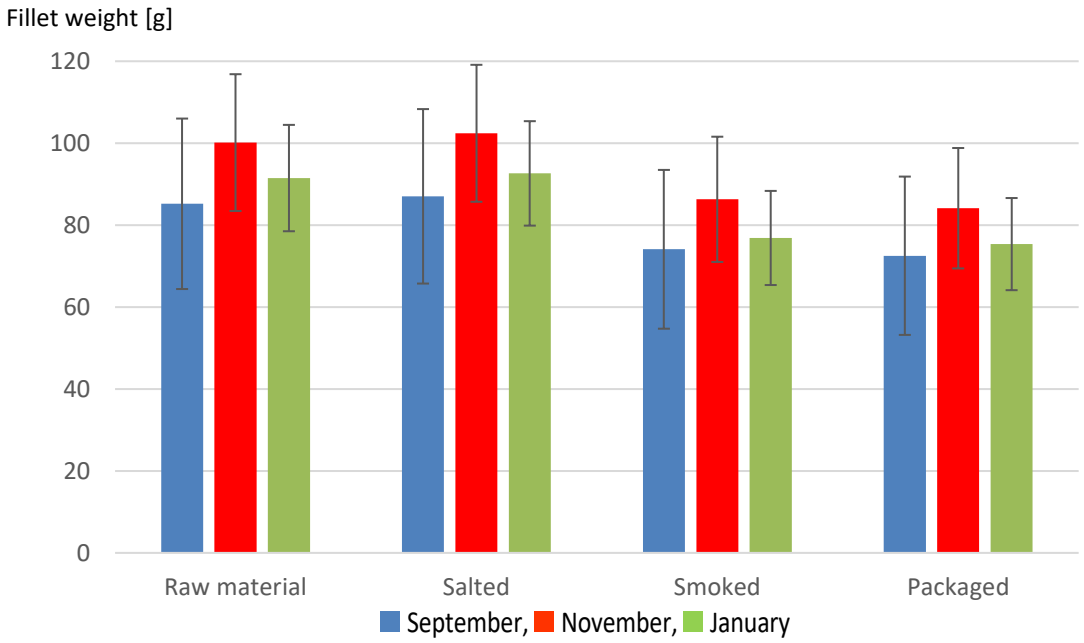

Figure 2 Weight (average ± SD) of samples from both trials throughout the smoking process.

These results show a somewhat lower total average weight of the September fillets, and a larger variation. The heaviest fillets were in the November group. The least variation could be seen in the January group, which was also the case for the fillets of trial 1.

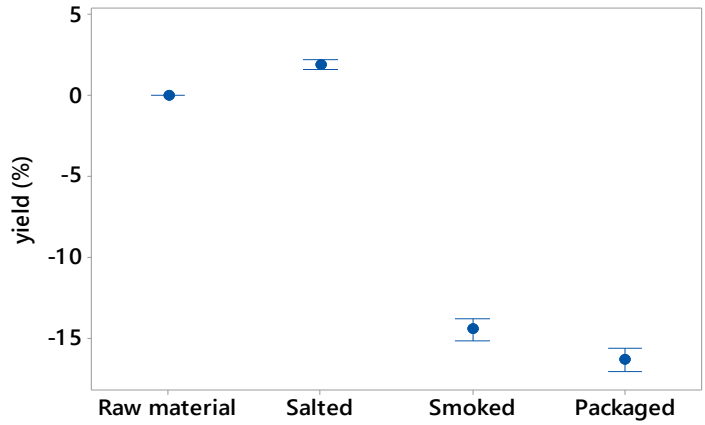

Figure 3 Total yield (average ± SE) of samples throughout the smoking process.

With respect to processing yield, the trends were similar (not statistically different) for all groups in both trials as indicated in Figure 3; a slight weight increase (1.9%) after salting, a substantial decrease (14.4%) after smoking and a further decrease after 1 week (packaged samples). The weight change after storage is reflected in the exudate results.

The determination of exudates was based on five fillets from each group at both samplings. The results are presented in Figure 4.

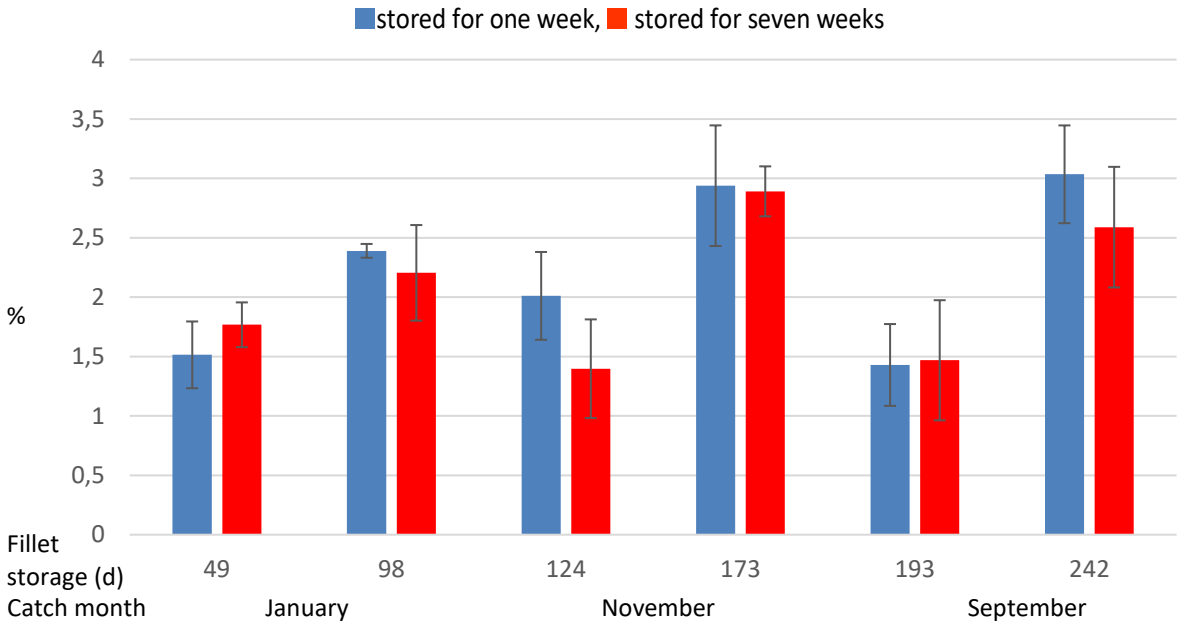

Figure 4 Exudates (average ± SD) in vacuum packaged product.

The results show that the amount of exudates increased with fillet storage time; i.e. all groups had higher amount of exudate after the second trial, than the first.

3.3 Color

Color is a very important quality characteristic for smoked mackerel. It is, however, not related only to the quality of the raw material, but maybe even more to the smoking process. In any case, it is important to monitor the color of the product, between groups and batches, but also through storage.

Examples of images from which the color analyses were performed are shown in Figure 5.

Figure 5 High resolution photos of samples from September (left), November (middle) and January (right), that were used for the color analyses.

The Whiteness, Redness and Yellowness (L*, a* and b*) – values that were measured from these images, are presented in Figure 6:

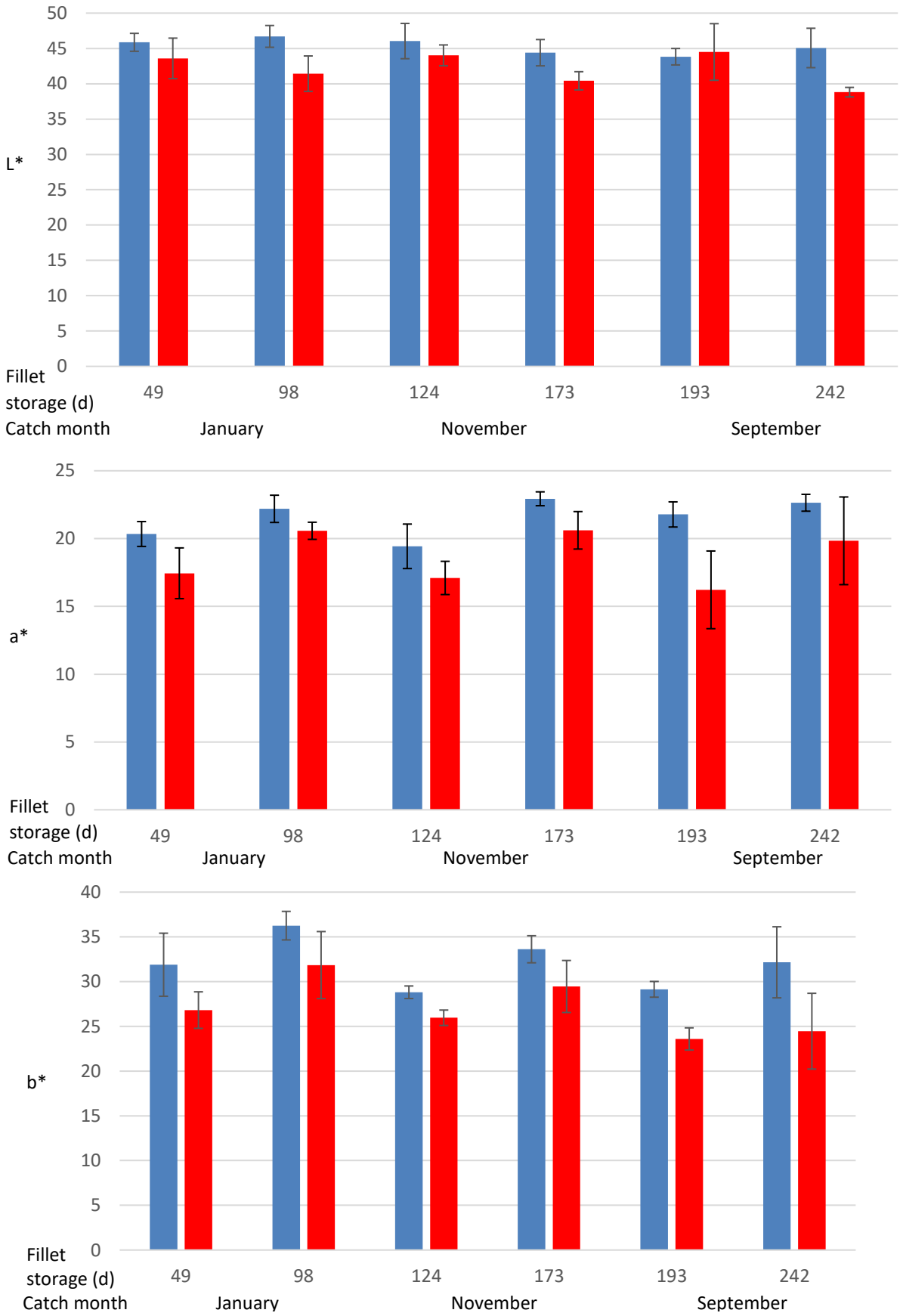

Figure 6 *L*, a* and b*-values (average ± SD) for smoked mackerel. (stored for one week, stored for seven weeks).*

Fillet storage time significantly ($p < 0.05$) affects all the instrumental color parameters (L*, a* and b*) of the smoked mackerel. Whereas Lightness (L*) decrease with increasing fillet storage, the redness (a*) and yellowness (b*) both increase.

Both redness and yellowness are significantly ($p < 0.05$) affected by catch month. And it is the January fillets that show the highest values for both redness and yellowness, and the September fillets the lowest.

The data show that storage also has significant ($p < 0.05$) effects on all color parameters. The smoked fillets become less light, and less red and yellow, during 6 weeks of storage.

Further, it appears that the three groups come out with quite similar colors in each trial, but the samples of the second trial are lighter and more red and yellow than those in the first trial. Whether this is an effect of fillet storage, or just a random variation in the process, is unclear.

3.4 Sensory analysis

As mentioned, the fillet storage time coincides with the three catch months investigated in this investigation. The results of the sensory analysis, focusing on these variables are presented in Figure 7.

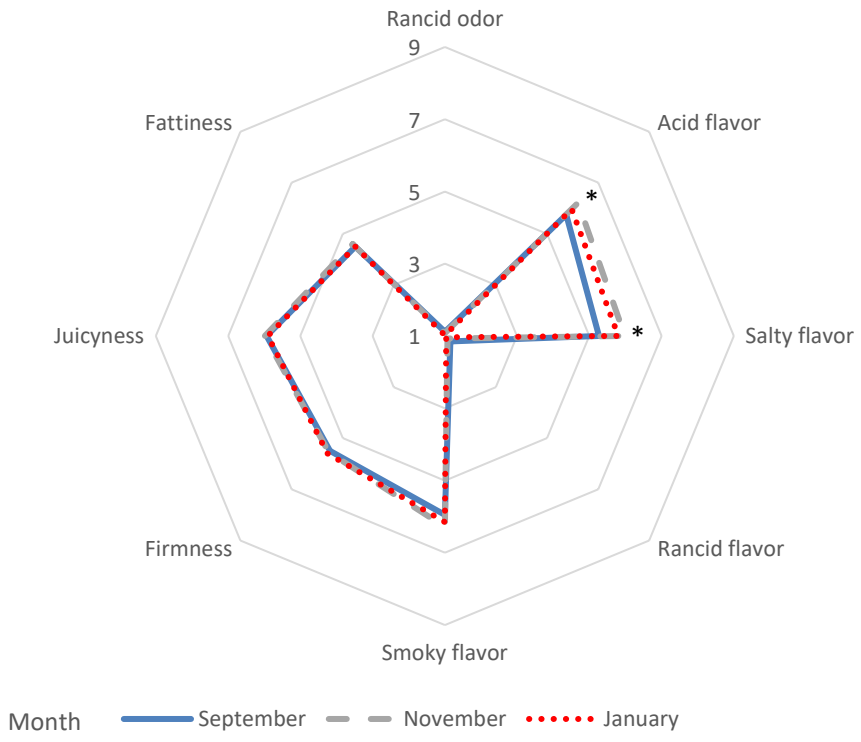

Figure 7 Average values of the sensory scores for the three different catch months included in the trial.

The sensory analysis showed no significant effects of the catch months/fillet storage time on rancidity parameters (odor and flavor). The acidic flavor was significantly affected by both the catch month and the fillet storage time, with the September fillets being the least acidic, and the January fillets, the most. The September fillets were also perceived as being significantly less salty than the two other

groups, which is in accordance with the chemical analysis. For the remaining parameters, there were no significant differences with respect to neither catch month nor fillet storage time.

The sensory results were also subjected to statistical analysis aiming to quantify the effects of product storage. The main results are presented in Figure 8.

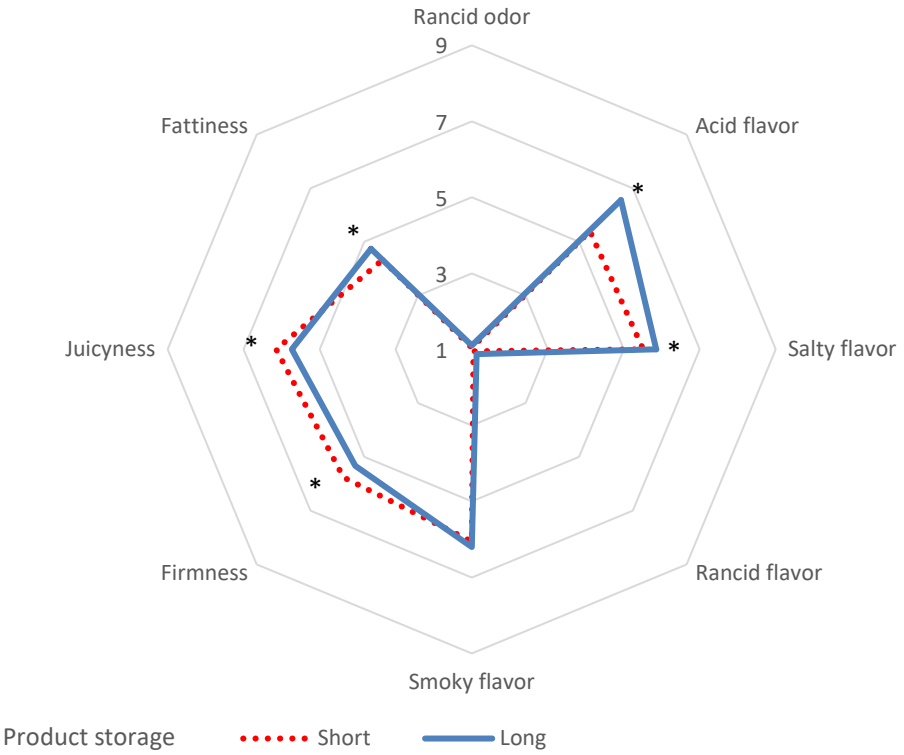

Figure 8 Average values of the sensory scores for samples stores for one (Short) and seven (Long) weeks.

The rancidity properties (taste and odor) of the vacuum packaged smoked mackerel were not significantly affected by the storage time (7 weeks). No significant effects of storage time could be detected on these parameters, in any of the two trials. Sensory properties that were significantly affected by product storage were firmness, juiciness, fattiness as well as acid and salty flavor. After 7 weeks of storage, the smoked fillets were perceived as more acidic, saltier, less firm and less juicy, but fattier than the products that were stored for only one week.

4 Discussion

The results indicate that the smoking process to some extent evens out the differences in mackerel fillet composition and quality. The fatty September fillets have lower salt content initially, after smoking. But the salt content seems to even out during storage. If the exudate had been higher, this could be due to fat release. But exudate figures are somewhat erratic and do not contribute much to explaining the other results.

The process yield was not significantly different between the groups, nor did fillet storage time give any significant effects on this parameter.

The significant effect of fillet storage time, leading to increased amount of exudate is somewhat challenging to interpret. It seems not to be consistent if the storage time of the groups is considered. In fact, after the first trial, the September group, with the longest storage time (193 days), had the lowest amount of exudate. Furthermore, it could be expected that the amount of exudate would increase over the storage period. This is often seen e.g. for cold smoked salmon (Birkeland & Akse, 2010). The higher process temperature and salt content may counteract this effect. And it may also be that the differences between the trials override this effect.

Most of the instrumental color measurements were affected by the investigated parameters. Whereas Lightness (L*) decreased with increasing fillet storage, the redness (a*) and yellowness (b*) both increased. All color parameters decreased after 6 week refrigerated vacuum storage, leading to darker and less red and yellow fillets.

In parallel experiments, sensory analyses of frozen stored fillets have indicated a maximum shelf life of six months. In these trials, fillets stored more than 8 months (September catch) were used. None of the samples were evaluated as rancid.

In both trials, the products originating from the three catch months and with frozen storage times varying from 2 to 8 months, were similar (not significantly different), in all characteristics but two (acid and salt flavor), as evaluated by the sensory panel. This implies that the smoking process seems to reduce initial difference, both in fat content and in freshness.

5 Literature

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